RAILWAY LOCATION AND CONSTRUCTION

B. H. McHENRY.

RULES

FOR

RAILWAY LOCATION AND CONSTRUCTION

USED ON THE

NORTHERN PACIFIC RAILWAY

BY

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WITH AN ADDITIONAL CHAPTER ON

ESTIMATING OVERHAUL IN EARTHWORK

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I.

Construction and Engineering Departments.

ORGANIZATION.

The Construction Department will have charge of all surveys and construction in connection with the building of new railways or extensions of existing lines.

The Engineering Department will have charge of all surveys and engineering connected with the work of improving lines already built.

The organization of the Construction Department will be as follows: (1) Chief Engineer, reporting to the President. (2) Division Engineers, with jurisdiction as assigned by the Chief Engineer. (3) Assistant Engineers in charge of the construction of a line, or other work of importance, reporting to Division Engineers. (4) Locating Engineers, reporting to Division Engineers or to Assistant Engineers as directed. (5) Resident Engineers, in charge of the construction of a section of new road, or a subdivision of some work, reporting to Assistant Engineers. The organization of the Engineering Department will be as follows: (1) Chief Engineer, reporting to the General Manager. (2) Division Engineers, having charge of the engineering work upon lines in operation, reporting to the Chief Engineer, and also acting as Division Engineers of the Construction Department upon special assignment by the Chief Engineer to such work. (3) Assistant Engineers, in charge of special work, reporting to Division Engineers.

The duties of the Engineering Department will be as follows:

1. To secure and maintain records of the physical charac-

teristics of the railway, including roadbed, track, ballast, bridges, culverts and other structures. The records should show number or quantity, location, type, dimensions, condition, cost and date of construction, in all necessary details.

2. To make general inspection of all such structures annually, and such other examinations in special cases as may be necessary at all times; to furnish reports on their condition, and estimates and recommendations covering repairs, renewals and replacements in the manner and on the forms prescribed.

3. To prepare and maintain correct station and right of way plats, standard track and other profiles, standard maps and plans, and all general engineering records.

4. To supervise and direct all work of special character, as assigned by General Manager and Chief Engineer.

5. To inspect and report condition of all ordinary and special work to insure compliance with standard plans and specifications.

6. To prepare plans, specifications and estimates for all duly authorized work, when necessary, to prepare forms of proposal and contracts for such work, and to award contracts when approved by the General Manager.

7. To furnish all necessary stakes, centers, elevations, cross sections and measurements required for the execution of routine or special work, and otherwise to aid and supplement the Division forces to the best advantage of the railway company.

Engineers will have no authority over roadmasters, bridge foremen or any regular force of the several Division Superintendents, except as it may be conferred upon them in special cases by the General Manager, General Superintendent, or Superintendent, but they must report to the proper official any neglect or failure to execute work in accordance with the duly authorized plans, specifications or instructions governing such work.

None other than routine work will be undertaken without formal and sufficient authority, confirmed by approved Improvement forms (1363), or by special direction of the General Manager, General Superintendent, or Assistant General

Superintendent transmitted through the Chief Engineer or the Division Engineers.

No work affecting the safety or regularity of trains must be undertaken without previously notifying the Superintendent of the Division upon which the work is to be performed, and the subsequent execution of the work must conform to the orders, rules and regulations established by the Superintendent to insure safety.

All necessary track or bridge work in connection with such work will be performed by the division force, under the instructions of the Superintendent or his roadmasters or bridge foremen.

Salaries and wages of special forces employed under the direction of an engineer, unless specially excepted, will be carried on the Superintendent's rolls, the engineer making time returns in the manner prescribed by the standard rules in force on the Division.

Before the beginning of each season's work Assistant Engineers will be furnished with a list of the various improvements authorized. The limits within which track laying and ballasting are to be prosecuted should be ascertained in advance and levels run over such sections and profiles sent to the Division Engineer, plotted to a double vertical and single horizontal scale. The Division Engineer will locate the proper ballast grade line and Assistant Engineers will compute quantities in cubic yards of material required for bank widening, raising sags and ballast.

At the close of each season's work Assistant Engineers will furnish a detailed report of the various improvements completed, giving full notes and sketches wherever necessary.

II.

Location.

THEORY.

"Engineering is the art of making a dollar earn the most interest."

A railway is a commercial enterprise and is constructed solely for profit.

The factors affecting profits are: 1. Gross earnings. 2. Operating expenses. 3. Fixed charges. The effect on such factors, of differences of route, location details and construction cost must be determined before the final route of least cost and greatest value can be fixed.

The combined sum of operating expenses and interest charges is least when interest charges on additional expenditures are no longer saved in reduced cost of operating expenses, and when additional operating expenses are no longer saved, in reduced interest charges. Accordingly, the economic value of each factor affecting the cost of operating must be ascertained and carefully compared with its corresponding effect on construction cost, in order to secure the most economical ratio between operating expenses and construction cost.

The principal factors affecting cost of operation, with which the Engineer has to deal, are: Volume of traffic, gradients, distance, rise and fall, curvature and maintenance of railway, for which economic values are elsewhere given under appropriate heads.

The sums which may be profitably expended for improving the character of the railway location and construction vary most directly with the number of trains to be operated over the new railway, for which reason the "train mile" is usually adopted as the operating unit. The commercial effectiveness of "operation" is reflected in the average cost of transportation per net ton mile, which may be regarded as the commercial unit.

The least cost of transportation is secured when the lowest train mile cost is combined with the largest net tonnage per train. And the earning power of the invested capital is greatest when least cost and greatest net tonnage per train are combined with the lowest economic capital expenditure.

Under these conditions only does "a dollar earn the most interest."

GENERAL INSTRUCTIONS.

The rules governing location are intended for use in the field, and it is expected that they will be closely followed.

The ability of the engineer will be determined by this standard.

Before any new road is located, the Chief Engineer will indicate the character and purpose of the line, and will give the number of trains for which the line is to be located. After the completion of the preliminary surveys he will also determine the rates and proper adjustments of the ruling grades and the maximum degree of curvature to be adopted. All locations must be approved by the Chief Engineer before construction is begun.

Each railway location should be specially considered with reference to its effect upon receipts, operating expenses, and fixed charges, the character and direction of the expected traffic and the class and number of trains to be operated over it. The selection of route, adjustment of location details and character of construction will be determined in accordance with the ascertained conditions of lowest operating expense and least construction cost for each case.

Locating engineers will furnish weekly reports, stating progress and giving all other items of general interest pertaining to their work, especially information concerning present or prospective sources of traffic, its locality, character and amount.

Strict compliance with the instructions is expected concerning the preparation of maps, profiles, records, and estimates.

Graphic tables for computing quantities on transverse slopes for use in preliminary estimates will be furnished by the railway company.

So far as practicable, all maps, profiles, estimates and general records will be completed while the surveys are in progress, avoiding all unnecessary accumulations at the close of the work.

Competent engineers will avoid much unnecessary loss of time and money by making preliminary reconnoissances in person, using pocket compass, hand level and "aneroid" when necessary. When there are several alternate routes careful examination will usually prove it unnecessary to make instrumental surveys over them all.

Rapid exploration lines, especially when in timber, should be run with compass bearings; in many cases the method of stadia readings will also expedite progress. The time-honored custom of conducting explorations from behind the transit should be changed for a more intelligent method.

The reconnoissance should be of an area rather than of a consecutive line, all lines or combinations of lines connecting controlling points being studied as a whole. It should be the effort of the engineer to first ascertain the position, character and limiting effect of controlling points, natural or otherwise; afterwards connecting such points most advantageously, and finally filling in intermediate details to the best advantages.

No local conditions of rocky slopes, swamps, brush, timber, etc., should be allowed to unduly influence the Engineer as to their real effect upon the total estimate. He should also remember that alternate lines will be compared upon the basis of completed cost, and not on the cost to subgrade only, and finally that it is not the object of location to secure a line of uniform low cost, but of least total cost. It is a common error to reject routes with short sections of heavy construction cost in favor of more uniform although inferior routes of greater total cost.

The route of best grades and alinement should always be first projected, working back to the final and most economical route. Working in the reverse order usually results in inferior location.

The possibility of obtaining a very good line should not preclude the search for a better one; the greatest and most costly location errors occur most frequently in prairie regions.

Valley locations are usually projected from "point to point" on the line of shortest distance, when the stream is unimportant, otherwise the convex angles of stream on one side and the slopes on the other form controlling points if not modified by the additional latitude of choice afforded by the two sides of the stream, or any combination of same.

Bench, plateau or prairie locations are usually projected on routes of most uniform grade and direction between controll-

ing points. Commercial centers, stream crossings and controlling elevations form the principal controlling points.

Mountain locations are subject to greater restrictions, and are usually fixed with reference to the position and height of the summit, the distribution and amount of rise and fall to be overcome, and the relation between the adopted gradients and the corresponding length and cost of line.

The summit is, of course, the principal controlling point; other points are generally accidental or artificial, as determined by local topographical conditions and the rate of grade adopted for the descent. Such lines are usually located descending from the summit along a uniform grade contour to an intersection with the "bottom" line of lower grades.

All locations should be made with regard to future permanent construction and every effort used to reduce the amount of temporary construction which may be required to the least limits. Many opportunities for stream diversion are neglected, even in cases where the cost of the bridging otherwise required is many times in excess.

When construction funds are limited, adopt lower standards of construction, lay temporary gradients and use short sections of temporary line around or over tunnels and sections of heavy work, if necessary to avoid sacrificing future benefits arising from a properly located route. Such lines may be economically revised at some future time, while the revision of a generally faulty "location" might involve such large expenditure as to make a remedy forever impracticable.

Exercise extreme care in fixing the locations for stations, water tanks, coaling plants and crossings, and in adjusting grades for same, to reduce the cost and disadvantages of train stops to the minimum.

Train stops on or near the foot of grades should always be avoided if possible, and when not avoidable for any reason, the rate of grade should be compensated to facilitate the starting of trains.

A proper reconnoissance report conveys a graphic impression of the features of the region and route traversed, and contains the fundamental elements affecting operation and construction cost. The engineer should separate the routes re-

ported upon into natural divisions of similar characteristics, giving distances, grades and controlling points of each. He should describe, classify and approximately estimate the material to be moved and other work to be performed, giving averages per mile and totals for each section, and furnish an approximate estimate of the cost per mile and total cost of the completed railway. Small scale maps and profiles showing general features, elevations and distribution of ruling grades should accompany such reports, whenever necessary.

The fundamental principle of good location is common sense.

VOLUME OF TRAFFIC.

Fixed charges are but slightly, or not at all, affected by variations in volume of traffic. "General" operating expenses are affected only by considerable changes of volume, while the more direct expenses of operation vary more or less closely with the tonnage or passengers transported.

The effect on cost of operation of the number of trains operated is much more direct, than of the actual number of passengers or tons transported, hence the effect on the cost per train-mile is used as the basis for all economic comparisons, and the actual cost per train-mile should be ascertained in all cases, when possible.

Under practical conditions, the first trains operated cost more, and additional trains cost less than the average cost of all.

The average cost per train-mile for the United States is probably not far from $1, and this amount may be used for convenience, when more exact data are lacking.

When the number of trains is affected without affecting the total cars or tonnage, the cost per train-mile added or saved, may be assumed at 60 cts. in default of more exact data.

The cost of assistant engine service, extra cost of heavier engines and of all other items affecting the cost per train-mile, under special conditions, must be added or subtracted from the train-mile cost first assumed (see Ruling Grades).

If better estimates of cost are not available, estimate assistant engines at $7,500 per annum (per day of 12 hours)

and heavier engines in the ratio of 15% increase of cost per train-mile for doubling weights on driving wheels. The total cost of assistant engine service should be divided by the number of trains served.

Passenger trains are but little affected in number or length by some classes of rise and fall and gradients, and should be excluded in all such cases.

For the purpose of comparison capitalize the annual cost of train expenses at 6%.

DISTANCE.

Minor changes not aggregating over two miles, in an engine stage, do not usually affect train wages, nor track force; train expenses and renewals are slightly affected.

The capitalized value of this class of distance per daily train per annum may be considered as 25 cts. per ft., to which should be added its construction cost, at say $3 per ft., when the actual cost is not known.

Greater changes, but not adding to the number of engine districts usually increase both train wages and track force. The assumed value of this class per daily train per annum is 60 cts. per ft. ($3,168 per mile). The actual construction cost should be added to the total thus obtained.

Considerable changes, adding to the number of engine districts and the number of trains operated, should be valued in accordance with the ascertained cost of similar service under similar conditions, but otherwise may be valued on the basis of $1 per train-mile, equivalent to $6,083 capitalized value per mile of distance per daily train per annum, adding all construction cost of railway and extra equipment to the amount obtained by multiplying this sum by the actual number of daily trains (each way).

The effect of distance on receipts is sometimes most serious, and a still further sum must be added in such cases, when the effect is sufficiently tangible.

CURVATURE.

The cost of operating curvature varies with the angular degrees of curvature operated, and is but little affected by the length of curve radius.

The operating value of curvature per degree is assumed at $7 per daily train per annum, but to this should be added the commercial value of lost time, if any, and also all extra construction cost of rail-braces, tie-plates, spikes and guard rails.

Curves exceeding 14° per station should not be used without due necessity and usually require both guard and "hold-up" rails for safety.

A maximum curve, unlike a maximum grade, is not limiting and does not justify the use of similar curvature elsewhere on the same engine district.

All curves of 3° and over must be provided with terminal transition curves, changing 1° with each chord of 50 ft. On mountain lines this rate of transition may be doubled if necessary.

Curves less than 300 ft. in length will not be used.

The minimum tangents between reversing curves must not be less than the chord length of the transition curves; the minimum tangents between curves in the same direction must not be less than 500 ft.

Curvature on maximum gradients must be compensated at a rate not less than .04 per degree.

Use standard rules for super-elevation of outer rail.

RISE AND FALL.

The effect on operation of minor gradients and small undulations, within "velocity limits" is very small, and its capitalized value is assumed at $2 per ft. per daily train per annum (one way). Limiting curvature and train stops on grades of this kind will greatly increase the cost of operation, and should be avoided in any event.

The value of rise and fall on grades of considerable rise exceeding velocity limits, but not requiring use of brakes and sand, is $7 per ft. per daily train.

The value of rise and fall on grades requiring the use of brakes and sand is $22 per ft. per daily train, and $30 per ft. if on ruling gradients.

The limiting effect on train weights, of long sections of more or less continuous rise, may considerably exceed that due

to maximum gradients. This effect occurs oftenest on valley lines with low ruling gradients.

Train weights may be limited either by ruling gradients which tax adhesion, or by time requirements, which tax the engine boiler.

The product of speed and train resistance is horse-power, and with fixed conditions of speed and engine horse-power, the train resistance is also fixed. Hence, the train weights over the division may be fixed by the average scheduled speed, and the engine horse-power at limits far below those fixed by ruling gradients. Under such conditions the average and not the maximum resistance controls the train weights.

Compute engine horse-power by the simple formula

$$P = \frac{R \times S}{375},$$

in which P is horse-power; R, resistance of total train in pounds; S, speed in miles per hour; and 375 a constant factor. (See Fig. 1 for horse-power of typical engines in use on the N. P. Ry. in 1898.)

Vertical curves are required on summits at all grade intersections not less than 50 ft. in length for each change of one-tenth in rate of grade.

In "sags" the rate of change should not exceed 0.05 ft. per station. In theory, the rate of change should be such as to maintain equality between the rolling resistance and the "acceleration of gravity" of each car throughout the varying rates of speed.

RULING GRADES.

Grades which limit the maximum weights and length of trains, are termed "Ruling Grades." Maximum grades, which may be operated by heavier engines, or by assistant engines, are not necessarily ruling grades.

The economic value of changes in rates of grades is determined by the relative total cost and number of trains required on each rate of grade to transport the same number of cars and tons. The practical rule is as follows: Multiply the daily number of trains saved or added by the ascertained cost per train-mile, by the length of the division in miles, and by the

number of days in the year, the result will be the annual saving or added cost, resulting from such change in rate. To obtain the capitalized value, divide this result by the proper interest rate.

When actual values are not known, assume the rate of 60c. per train mile (see Volume of Traffic), which capitalized at 6% is $3,650 (one way only).

The cost of operating heavier engines, assistant engines and all other items of expense added or saved, should be computed in addition and capitalized, if necessary (see Volume of Traffic).

Every effort must be made to maintain the lowest practicable and economical rate of grade over the entire engine district.

When sections of high grade are unavoidable, it is frequently practicable to concentrate such "rise and fall" into short sections, which may be economically operated by use of assistant engines.

The ruling grade of each engine district should be adjusted with reference to those of the adjoining districts, or to conditions of local traffic, in such a manner as to avoid unnecessary "breaking and making up" of trains. When not practicable to secure this by grade adjustment alone a combined adjustment of grades and engine, weights will effect the same end.

The ratio of rates of ruling grades to each other at points of intersection should preferably be in proportion to the tractive powers of the available types of engines.

On sections of great rise and fall (mountain crossings, etc.) it should be the aim of the engineer to produce the maximum and minimum ruling grades to an intersection, if possible, and in any event to reduce the sections of different rates to the least number.

Ruling grades may be of different rates, but equal limiting effect, when adjusted for unbalanced volume of traffic.

Train stops on maximum grades must be compensated as fully as practicable, and not less than 3.5 ft. in any case. Compensation is not only provided for the increase in starting friction over rolling friction, but in addition to permit trains

to acquire speed more rapidly. Train stops near the foot of a long grade are most limiting in this respect.

VIRTUAL GRADES.

The motion of a train represents stored energy, derived from the engine or gravitation, and, under appropriate conditions, the power of the engine may be in part absorbed in imparting speed to the train, or augmented by the surrendered momentum of the train.

When rolling and grade resistances exceed the applied force, motion is retarded and energy released in definite proportions, and conversely, when the applied force is in excess, motion is accelerated and energy imparted in like proportions.

The moving energy of the train at different speeds is given in Fig. 2 in terms of "Velocity Head," which is the vertical height, through which the train would be lifted, at each degree of speed by its momentum alone.

The engine tractive power is least at high speed and short "cut off" and greatest at low speed and "full stroke," as shown in Fig. 1.

The mean tractive power of these engines from different rates of speed to ton miles per hour is given by the table, Fig. 1, or may be deduced from the diagram on the same sheet.

The maximum available power for overcoming rolling and grade resistance is represented by the product of the train weight and its velocity head, added to the product of the mean engine tractive power, and the time or distance over which the power is exerted, illustrated, in short, in the effect produced by "taking a run at the hill."

Rolling resistance for trains at all speeds is given by Fig. 3, from which mean resistances between different rates of speed may also be readily computed.

The simplest rule for computing grade resistance is as follows: Resistance (in lbs. per ton) = rate of grade (in feet) × 20.

A gradient of equivalent resistance to the force exerted by the engine is the "virtual grade," or real resistance taxing the engine cylinders. The virtual grade line may be plotted with

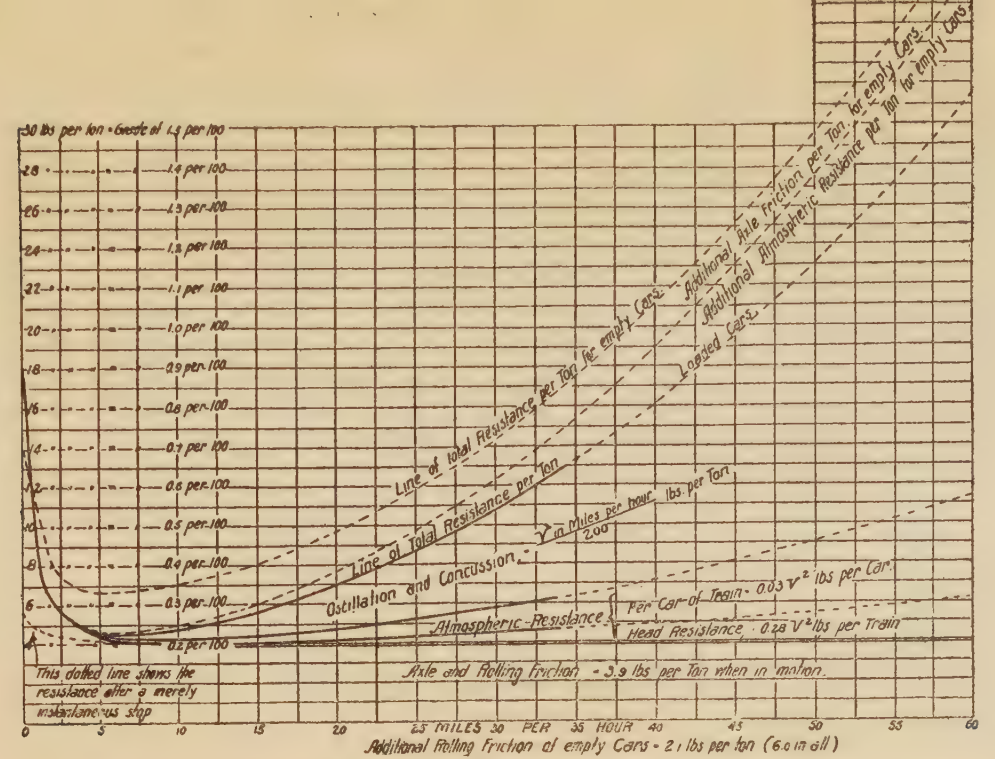


FIG. 3.—DIAGRAM OF TRAIN RESISTANCE IN POUNDS PER TON.
(From A. M. Wellington's Economic Theory of Railway Location.)

the assistance of Figs. 1, 2, and 3, or computed in accordance with the general principles before given.

"Momentum" or velocity grades may be used with due caution to avoid increasing rate of ruling grades, or to avoid large construction expenditures otherwise necessary. In all such cases train stops, grade crossing and limiting or dangerous curvature must be avoided.

Velocity grades requiring freight train speeds in excess of 30 miles per hour must not be used, nor should such grades be laid out for speeds in excess of that obtainable under ordinary working conditions.

MAINTENANCE AS AFFECTED BY LOCATION.

The cost and difficulty of maintaining track and road bed may be greatly affected by the general characteristics and local details of the selected route, and all such conditions should receive careful consideration during the location of the route.

The greatest differences may exist, even between the two sides of the same valley, as one side may be subject to contingencies of drifting snow, slides, cloud bursts, stream encroachments or "washouts," from which the other side is wholly free. Conditions of greater shade, due to forest or bluffs, may cause longer duration of snow, frost and moisture, or local peculiarities of soil, and the character and number of lateral streams to be crossed may all contribute towards the increased cost of maintenance.

Additions to cost of maintenance arising from faulty details of "construction," may not be properly considered in connection with the subject of "Location," unless resulting directly or indirectly from the character of the location, such as unnecessary increase in number and length of bridges, grade crossings in lieu of possible under or over crossings, faulty arrangements of grades, affecting yard and station expenses, and other items of like character.

All additions to operating expenses, arising from such

NOTE.—The table of "Velocity Heads" and the economic values given for "Distance," "Curvature," and "Rise and Fall," are derived from Wellington's "Economic Theory of Location;" the values have been capitalized at 6%.

causes, should be included in equations of alternate route, capitalizing same if necessary, at the ruling rate of interest.

III.

Surveys and Construction.

SURVEYS.

The railway company will furnish instruments, transportation, camp equipage and subsistence while parties are employed in the field. Each individual will provide himself with all personal articles, such as drawing instruments, clothing, blankets, etc.

All survey lines diverging from any constructed line must be connected with it by measurement, so that the initial point can be located upon the map of such constructed line.

Stations will be uniformly 100 ft. long each, and numbered consecutively. It is not necessary to set stakes at each station in all cases on preliminary lines; this may be left to the discretion of the chief of the party. Mark stakes on alternate lines with distinguishing letter A, B, C, etc. Mark stakes on located lines "L." Mark point of curvature "P. C." or "P. S.;" point of tangency "P. T." on the stakes of the beginning and end of all curves. Mark stakes at the "P. C." or "P. S." with the degree and direction of the curve.

Ties must be secured to all township and subdivision lines whenever crossed. Give station number of intersection, angle of intersection, distance along the line to the nearest corner or quarter corner. Whenever possible, make the intersection by running through between the two corners.

When line is located through villages or towns, take necessary measurements, tieing the center line to the plats, and secure tracings of the town plats as contained in the county register's office, with all dates and certificates contained in original, and send these copies to the office of the Chief Engineer.

Tie in all property and land lines, and locate all buildings that are near the line.

Check all angles by needle reading, or by doubling the angle

or both. Check all measurements by chain or tape. Check chains frequently by steel tape or level rod.

Keep all instruments in proper condition and good adjustment.

Always establish a substantial and permanent bench at the initial point of all surveys, and at short intervals along the line. Use the sea-level datum, and if one has to be assumed, ascertain its relation with the standard datum at the first opportunity, and correct all elevations accordingly.

All level notes must be checked at the end of each day's work by adding the backsights and the foresights, and ascertaining the difference.

MAPS, PROFILES AND RECORDS.

Maps of located lines, made in the field, will be usually drawn to a scale of 1 in. to 800 ft.; in broken and difficult localities, 1 in. to 400 ft. General maps to be sent to the office of the Chief Engineer may be drawn to a scale of 1 in. to 4,000 ft., etc. The maps will be made in conformity with the standard specimen sheets furnished from the office of Chief Engineer.

Maps, plans and profiles are to be drawn with the top of the paper to northward or westward, and the letters and figures are to be right side up toward the top or toward the left hand side of the paper, and must otherwise conform with the specimen profiles.

Maps and profiles should give names of all rivers and streams, names of owners or occupants of houses, ranches or farms passed by the line, etc. Put on all the information necessary to enable another person to fully identify any locality. Be certain to note on profile all extreme high or extreme low water marks, wherever found, even if only approximate. The meridian should be drawn on all maps, both true and magnetic, when both are known.

On each drawing of any kind, put name of engineer, initial of draftsman, date, place, etc. On both ends of the outside of the paper, give the title in full of the map, plan, sketch, or profile.

Tracings of maps and profiles of all lines run must be sent

to the office of the Chief Engineer, distinctly marked with the name of the line, streams, and all other information necessary to identify the locality.

Tracings of located lines showing government and property lines, streams and date of commencing and completing survey, must be made and sent promptly to the office of Chief Engineer, as soon as each section of 20 miles has been finally located, for the purpose of filing map of definite location in the land office.

All changes of line made after the map of definite location has been filed in the general land office must be approved by the engineer in charge before being adopted, and as soon as made, reported to the Chief Engineer with a tracing of new and old line, and tracing profile of the part altered.

Topography on general maps should be given for a distance of 1,500 ft. on each side of the center line, and further when necessary to show important features. In order to facilitate plotting contour topography, the notes should give distances of contours from the center line.

All courses of line must be given in reference to the true meridian, and for that purpose an observation must be taken upon starting the survey and the true course recorded in the field books, as the work progresses. An additional observation should be taken for the correction of meridianal convergency whenever the extent of the survey shall attain a departure of one-half degree of longitude.

Curves and bearings of tangents shall be noted on the maps and profiles in the manner shown on the samples furnished. When practicable give true bearings instead of magnetic. State which is given.

To avoid cumulative errors, when platting lines, all angles must be laid off from some standard bearing, using the calculated course for this purpose. This can be done best by laying off any convenient bearing in the general direction of the survey and transferring all angles turned from this line by parallel rules or triangles, to the last point scaled. This will, on located lines, require all tangents to be calculated from intersection to intersection.

Indicate on the map, or otherwise, the width and extent of

extra right of way necessary for stations, side tracks, "Ys," borrow pits, etc., on the line of the road.

Profiles, when completed, shall contain all the information called for on the sample copy furnished from the office of Chief Engineer, and arranged in the manner shown thereon. The original profiles must be made on the regular profile paper. Tracings must be made in sections of 20 miles from the original profile, and sent to the office of Division Engineer, from which the necessary blue-prints will be made for contractors. Intersecting grades are to be connected by vertical curves having a rate of change of grade per station of 0.05 ft., except on summit curves where the rate of change may be 0.1 ft. or more per station.

Profiles should show alinement drawn in red near the bottom of the paper. The direction of the curve is shown by drawing the radial lines to an intersection on their proper side, at the middle of the curve.

Progress profiles will be sent each month to the Chief Engineer's office, properly colored to show all work done to and included in the last estimate, on the part of the road in charge of the engineer. These profiles must show all work done during the preceding month; not only grading, but details of bridges and culverts built, with their exact location; description and location of all buildings, or structures of any kind, wells dug, main track, sidings, or "Ys" laid, etc. The depth that piles are driven below the surface of the ground should be indicated by dotted lines, showing the point of lowest pile in bent; the mud sills of trestles should be shown by a short heavy line, and on steep side hills the elevation of each mud sill should be indicated in the same way. Prints from "Solar" negatives of tracing profiles in the Chief Engineer's office will be furnished for progress profiles. The completed profiles will be retained in the office of the Division Engineer at the close of the work.

The standard progress colors are as follows:

January ..... Chrome yellow.	July ..... Sepia.
February ..... Carmine.	August ..... Emerald green.
March ..... Payne's gray.	September ..... Cobalt blue.
April ..... Deep chrome.	October ..... Vermillion.
May ..... Prussian blue.	November ..... Indian red.
June ..... Burnt Sienna.	December ..... Sap green.

Track profiles must be prepared in all cases when necessary for the guidance of the contractor, showing, in addition to the ordinary alinement notes of the profile, the number and length of rails to each tangent, the number of long and short rails in each curve, and the ordinates to which they are to be curved.

Field books must indicate each day's work, giving date. The fly leaf of each book must show in ink the name of the branch or division, nature of survey, kind of notes, name of engineer, name of instrumentman, or topographer, and the terminal points contained in the book. See that all subjects contained therein are properly indexed and that all notes of adopted or abandoned lines are properly marked as such. Have notes so plain that they may be understood by any one.

The original field notes should be sent in to the general office when the survey is completed. In case the original notes are not in good condition have them copied in new book, giving a revised and complete record of alinement, levels, topography, right of way notes, and other data pertaining to the line.

Diaries will be furnished to engineers and instrumentmen on construction. Details of each day's work must be entered, giving dates of staking out work, commencement and completion of work on excavation, bridges and buildings; rise and fall of streams, and other data of future value. These diaries must be returned to the Assistant Engineer at the close of the work.

RIGHT OF WAY.

As soon as the construction of a line has been ordered the Division Engineer will issue the necessary instructions for securing the right of way, which will be uniformly 100 ft. in width, except where additional land is required for station grounds, borrow pits, wide slopes, or other purposes.

The right of way should be secured as rapidly as possible, contracts for same being taken and forwarded immediately to Division Engineer's office, where deeds and vouchers will be made.

The right of way agent will be under the orders of the

Division Engineer, but will consult freely with the Assistant Engineer in charge of the line, and will make all agreements as to fences, cattle guards, road crossings, ditches, etc., subject to his approval.

The description of irregular tracts which are acquired by the company will be by metes and bounds, obtained by actual survey. The description of right of way through government subdivisions will be made in the following form:

A strip, piece or parcel of land one hundred feet in width, situated in the northwest quarter of the northwest quarter of section 10, in township two north, range one west (S. 10, T. 2 N. R. 1 W.), Madison county, Montana, and having for its boundaries two lines that are parallel with and equidistant from the center line of the railroad of the ..... Railway Company, as the same is now located (and constructed). For a more particular description, reference may be had to the plat drawn upon and made a part of this deed.

The description of lots in platted tracts should be in the following form:

Lot seven (7), block six (6), in Smith's addition to Helena, Lewis and Clarke county, Montana, according to the recorded plat thereof.

All plats drawn upon deeds should give ties to the government survey points or to some fixed and indestructible points, so that the land can be located from the description and the plat.

As soon as the right of way has been definitely secured, plats of the same will be prepared in Division Engineer's office, conforming to standard scale and plan furnished by Chief Engineer, to whom they will be forwarded when completed, accompanied by the deeds.

ESTIMATES.

A careful estimate must be made showing the probable cost of every located line and of every structure or special work upon which a report is ordered. Great precaution must be taken to include everything necessary to complete the work ready for operation or use. This applies to work to be done by both the Construction and the Engineering Departments.

In case it is necessary to make the estimate before the exact quantities are determined, it must be replaced by another whenever the data can be obtained.

In monthly and partial estimates, make returns of grading to nearest ten yards, and masonry to nearest five yards.

Monthly statement (form 106), showing expenditures to date and comparison with the preliminary estimate, will be prepared by Assistant Engineer at the close of each month and sent to Division Engineer, who will note and forward to the Chief Engineer.

No estimate or statement of quantities will be given to contractors or sub-contractors not bearing the certificate of the Assistant Engineer.

The standard record book, form No. 62, of the Company, will be furnished each engineer in charge of a residency. The notes are to be written in ink, when final. The record should contain cross-section notes, and all other data pertaining to calculation of quantities, classification in detail, ground and grade elevations, alinement, material or labor accounts; and the data for every item embraced in the final estimate. A summary will be made giving the final estimate in sections of one mile, conforming to the mile-posts of the branch or division. The record must be kept up, as far as possible, while work is in progress, and must be turned in to the Assistant Engineer at the close of the work, and finally checked in the office of the Division Engineer.

GENERAL.

The plans and work of the Company are its private property, and must not be imparted to any one. Reports must be made to the immediate superior of the engineer or employee, and to no one else.

The rates of pay of all employees will be fixed by the Chief Engineer, and no change of rate so fixed shall be made without his authority first obtained.

Damage, destruction or loss of property of the Company through carelessness or wilfullness, must be made good by the individual at fault.

Engineers in immediate charge of parties are responsible

for all Company property in their charge, and are expected to prevent extravagance and waste in the use of supplies of all kinds furnished by the Company.

Locating and resident engineers will forward a weekly report to their superior officers, reporting progress of work and all other general items of interest, pertaining to the work. This will be accompanied by force report, form 138.

All engineers must make themselves familiar with the conditions of the contracts and specifications for work under their charge; they should attend to any reasonable request of contractors, furnish them heights, lines, stakes, plans, etc., whenever necessary, and in general do all things requisite to enable contractors to work to advantage and without delay.

During construction each line will be divided into residencies of convenient length, as directed by Division Engineer, each in charge of a Resident Engineer, and provided with such assistants, camp equipage, transportation, and other outfit as may be necessary.

The nature of the work and the various facilities must be carefully considered as soon as the construction is ordered, so that competitive proposals may be obtained for everything that will be required.

Each Assistant Engineer in charge of a line will submit, for approval of the Division Engineer, a list of all buildings, sidings, Ys, etc., with proposed location of same, required on his work. The Division Engineer should submit all proposed plans for station or terminal facilities to the proper officials of the Operating Department for criticism, and their suggestions must receive careful consideration.

The arrangement of all stations and terminals and the appurtenant tracks, the location of water tanks, and all matters having a bearing upon the operation of any line, should also be submitted for criticism before construction

Engineers must prosecute their work economically and will be expected to work to the estimates closely.

All structures will be built in accordance with the standard plans of the Company, and no deviation will be made from same except by authority of the Chief Engineer. Standard

plans will be furnished from Chief Engineer's office, and at the close of each piece of work all that have been used on same, by engineers or contractors, will be returned to Division Engineer.

The usual classification of grading will be earth, loose rock and solid rock. If cemented gravel or soft rock in place or other distinctive material exists in considerable quantities, the fact must be reported to the Chief Engineer in order that it may have a proper classification assigned to it.

In staking out grading, have number of station marked on face of center stake, and cut or fill on its back. On slope stakes have cut or fill marked on the face, and number of station on the back.

Banks must be made full and regular. Care must be taken to avoid sags between stations. The roadbed throughout must conform strictly to the standard plan.

In regions swept by strong winds, where the snow-fall is liable to be great and drifting to occur, all structures will be put on that side of the track opposite the prevailing winds. Usually this will be the southerly side, and station buildings, water stations, switch stands, and every kind of structure that can cause the formation of drifts, will be put on that side. Sidings and spur tracks should be put on the same side, where practicable.

When embankments are rip-rapped to protect them from action of water, that part of embankment upon which the rip-rap is placed should generally be made with slope not less than two to one. If the embankment has been finished at a steeper slope, the rip-rap should usually be so placed that its exterior slope shall be two to one.

Surface ditches must be laid out with great care to prevent water from running down the slope or cut, or against embankments, or being carried to any point where it can act injuriously upon any part of the work. The ditches should be made of ample size; not less than one foot wide at the bottom in any case; and if the area is considerable from which water may accumulate, they should be made two feet wide or more at the bottom. Material excavated in their construction should usually be thrown on the side toward the cut. In few mat-

ters is there more opportunity to show good judgment than in judiciously disposing of surface water about cuts. All cuts must have surface ditches and thorough drainage.

In turning streams care must be taken to make embankments across old channels strong enough to resist the action of currents. In such cases the width of the embankment should usually be made not less than ten (10) feet from the center line on the side against which the current will act, with slope of two to one. In cases of soft, spongy, or sliding material, this width should be increased on the exposed side. It should be borne in mind that it is less costly to build an embankment with excess of strength at first, than to have it washed out and be compelled to rebuild it.

In turning rapid, turbulent streams, take special and full precautions to prevent the new embankments from being washed away while building before they are high and strong enough for effectual resistance.

In building culverts and other waterways of perishable materials, ample allowance in size must be made for reconstructing them at a future time of durable materials. Wherever practicable iron culvert pipes should be hauled ahead and placed in position before the embankments are completed.

Vitrified tile pipe of double strength will be used under road crossings.

In building permanent box culverts of stone or brick, the smallest opening to be allowed is 9 sq. ft., clear of all obstructions. The height of the opening of a culvert should never be less than its width. The greatest care should be taken to secure the foundations of all culverts and water conduits.

Stream diversions, even when of considerable magnitude, usually prove much cheaper in first cost and also in subsequent maintenance than the bridging otherwise required, particularly when the excavated material is used in embankments.

The natural "scour" of the stream may sometimes be relied upon to widen channel excavations of small original cross-section, but in all cases due precautions must be taken to insure final cross-sections of full and ample proportions.

Pile and trestle bridges, not required in part or in whole for water-way, are too frequently constructed in order to save

time or to avoid real or supposed difficulties in forming the embankments. The maintenance cost of such bridges is many times in excess of that of embankments of equal first cost, and no bridges of this character should be built unless the cost of the embankments otherwise necessary exceeds both the first cost of such bridges and the subsequent cost of filling same by train or otherwise.

Thorough drainage is a maxim to be impressed on the mind and practice of every one engaged in construction, and engineers must beware of being deceived or misled in so-called "rainless districts," for experience proves that sometimes (perhaps at long intervals), most destructive and uncontrollable floods occur in such localities.

Top of bridge stringers will be set 0.25 ft. above regular profile grade, and regular grade changed about 100 ft. to meet it. This will apply in all cases, unless otherwise ordered.

In the construction of pile and trestle bridges a competent inspector should be retained, whose duty it shall be to keep a record of all piles driven. The inspector's record must show length of piles, depth to which each pile is driven, sinking in inches by the last three blows of the hammer, weight of hammer, and fall in feet of same, and amount of piles cut off.

Engineers should endeavor to secure, wherever practicable, at reasonable expense, undergrade or overhead highway crossings. Bridges and culverts can frequently be utilized at slight expense for undergrade crossings for stock by making necessary openings in right of way fence.

Before the completion of the work, all construction material left over and scattered along the line must be picked up and returned to the material yard. Refuse will be burned or otherwise disposed of.

IV.

Track and Ballast.

PREPARATION OF ROADBED.

The standard width of single-track roadbed at sub-grade is 14 ft. on embankments, 20 ft. in earth cuts, and 16 ft. in rock cuts unless otherwise ordered.

All narrow banks must be widened to the standard width from centers, as established by the engineer.

Transition curves will be used at the end of all curves of 3° and upwards. The rate of change per degree of curvature should preferably not exceed 1° for each chord of 50 ft. in length, except on mountain grades, where the chord may be reduced to the minimum length of 25 ft., when necessary.

Short sags should be avoided, and in all cases vertical curves should be provided at grade intersections, for which the engineer will establish line and grade wherever required.

The roadbed at sub-grade should be crowned to facilitate drainage by raising the center 4 to 6 ins. higher than the sides, making due allowance for ballast in establishing final grade elevation.

Ditches in cuts should be taken out in accordance with the standard cross-section as follows: In earth, 3 ft., wide at sub-grade, 1 ft. deep, with side slopes 1 to 1. In rock 1 ft. wide at sub-grade, 1 ft. deep, vertical sides.

Material used for ballasting, widening banks or raising sags should be procured at points where the removal of same will benefit the roadbed by widening cuts, reducing grades or ditching. Engineers will give this subject their special attention.

TIES.

The number of ties per rail will necessarily vary with the width of the ties furnished, and will usually be from 15 to 17 ties per rail length. The minimum width between ties must not be less than 10 ins. On construction, ties will be laid 2 ft. c. to c., or 2,640 ties to the mile.

The best ties will be selected for use at joints, with faces not less than 8 ins. nor more than 10 ins. wide, and must be so placed that the outside bolt will come about the center of ties; the maximum spacing between ties at joints must not exceed 10 ins.

"Rail cut" ties must be adzed to uniform bearing, old spike holes plugged, and joint ties properly spaced for suspended joints, after the new rails are laid, and before the ballast is distributed.

In order to maintain the standard gage, three lines of spikes must be drawn if old steel rails are replaced by rails of wider section.

DISTRIBUTING RAILS.

The rails may be distributed either from the ends or sides of train. If distributed from the sides, both ends of rail must be dropped simultaneously. Skids will invariably be used whenever necessary to unload into piles. In all cases the greatest care must be used to avoid injury to rails by dropping them on hard substances or uneven surfaces.

CURVING.

Rails in curves of over 2° must be separately curved, and before being placed in track. An Emerson rail bender or bender of similar type will invariably be used for this purpose. The sledging of rails is positively prohibited.

Particular care must be given to insure uniform curvature of the rail throughout its length, in accordance with the following table of middle ordinates:

TABLE OF MIDDLE ORDINATES.

Degs.	Ins.	Degs.	Ins.	Degs.	Ins.	Degs.	Ins.
1	¼	6	1 7/16	11	2 9/16	16	3¾
2	½	7	1⅝	12	2 15/16	17	4
3	11/16	8	1⅞	13	3 1/16	18	4¼
4	15/16	9	2⅛	14	3 5/16	19	4½
5	1 3/16	10	2⅜	15	3½	20	4 9/16

NOTE.—Ordinate at quarters equals three-quarters of middle ordinates.

PLACING OF RAILS IN TRACK.

The rails must be laid to line and gage, and placed in track consecutively, throwing out both rails from the old track ahead, as the new rails are laid when track is relaid. Split points will be used for closing track for passage of trains. Accurate expansion cannot be secured if long stretches of rails are fastened up to one side of track and subsequently thrown into line, and this method is prohibited.

The track will be laid with even joints on tangents and broken joints on curves, except on sections of frequent curvature and short tangents less than 1,000 ft. in length, where broken joints will be maintained throughout.

To pass from even joints on tangents to broken joints on curves, cut and use a rail according to the following rule:

Cut rail at point distant from center of rail one-half inch for each degree of central angle of curve, using short rail on inner side of curve. For consecutive curves with short intervening tangents, obtain the separate sums of right and left central angles, subtract the lesser from the greater, and the difference will be the required angle. Use short rail on inner side of this angle. The length of the short rail must not be less than 10 ft.

"Short rails" may be used in inside line of rails in curves of large central angle, in order to maintain position of joints near center of outer rail, and in such cases the above rule must be modified correspondingly. Notes for length of cut or short rails will be furnished in advance by the engineer.

Track centers will be furnished by the engineer every 200 ft. on tangents, every 50 ft. on curves, and every 25 ft. on easement curves. The track must be laid to conform accurately to the line established.

To insure perfect alinement at rail ends, the rails should be brought squarely together, the splices placed, and carefully bolted before spiking. Perfect alinement at rail ends is of great importance in order to prevent excessive flange wear.

The position of the brand on the rail is immaterial, whether right or left, inside or outside, but its position must be uniform with the contiguous rails, and the brand should not be alternated on the same line of rails.

When relaying track, a convenient method of unloading rails from end of car is by means of two 30-ft. lines, equipped with grab hooks on each end, one end to be made fast to joints and the other end to slots in ends of rails, using the engine for moving the cars. This insures proper spacing, and is more economical than unloading from the sides. Use roller at end of car when drawing off rail.

EXPANSION.

Proper allowance must be made for expansion, according to temperature, as follows:

Temp., degs.	Ins.	Temp., degs.	Ins.	Temp., degs.	Ins.
100	0	60	1/8	20	1/4
80	1/16	40	3/16	0	5/16

Proper expansion must be secured by the use of iron shims, provided in accordance with the above specifications, except where track is laid on a steep grade, when sawed wooden shims of proper thickness will be provided. These shims must be left in place until track is full spiked, bolted and thoroughly anchored.

In order to prevent rails from "creeping," it is absolutely essential that each individual rail shall be so thoroughly anchored as to insure freedom from contact with adjoining rails. Creeping cannot be prevented if a number of consecutive rails are in contact.

BOLTING.

The Harvey grip, or other improved form of bolt, should be used. At the time the rail is laid, two bolts should be placed in each splice, and tightened sufficiently to hold rails in line. The remaining bolts should then be placed and tightened as soon as possible. Nuts should be tightened a second or third time within 30 days after track is laid.

Inspect the rails before angle bars are tightened, and take out kinks or bends by the rail bender. The nuts must be screwed up firmly before joints are spiked.

GAGING.

The standard gage will be as follows:

On tangents	.....	4 ft.	8½ ins.
On curves of 1, 2 and 3 degrees	.....	4 "	8⅝ "
On " " 4, 5 " 6 "	.....	4 "	8¾ "
On " " 7, 8 " 9 "	.....	4 "	8⅞ "
On " " 10, 11 " 12 "	.....	4 "	9 "
On " " 13, 14 " 15 "	.....	4 "	9⅛ "

The extra width of gage on curves should be uniformly decreased or tapped off, on the easement curve, from point of full curve to point of tangent.

Joints and centers should be gaged first, and the track gage must be applied at as many points as may be necessary to insure perfect and uniform gage.

Easement curves must be spiked to gage at five different points within each rail length, and all track must be accurately gaged when spiked.

Suitable track gages for use on tangents and curves, which

will insure the retention of the proper gage during the operation of spiking, must be used. All track gages must be tested by the engineer or roadmaster at the beginning of the working season, and the date of inspection recorded.

SPIKING.

Track must be full spiked, with inside and outside spikes driven in opposite sides of the tie. Spikes must be set half their own width from edge of rail and driven vertically to a full bearing on foot of rail. The prevalent practices of driving sloping spikes, or of giving them a final lateral blow to close the spikes against the rail, will not be permitted. So far as possible the spikes will be driven in the best wood in the tie, which is usually at the outer edge, and must not be redriven in old holes.

ELEVATION.

The elevation (in inches) of outer rail upon curves will be made in accordance with the following table:

TABLE OF ELEVATION OF OUTER RAILS ON CURVES.

Degree of curve.	Rate of speed in miles per hour.								
	15.	20.	25.	30.	35.	40.	45.	50.	60.
	Superelevation in inches.								
1	1/8	1/4	7/16	9/16	13/16	1 1/16	1 5/16	1 5/8	2 3/8
2	5/16	1/2	13/16	1 3/16	1 5/8	2 1/8	2 11/16	3 3/16	4 3/4
3	7/16	13/16	1 1/4	1 3/4	2 7/16	3 1/8	4	4 15/16	7 1/16
4	9/16	1 1/16	1 5/8	2 3/8	3 1/4	4 3/16	5 5/16	6 5/8	....
5	3/4	1 5/16	2 1/16	3	4	5 1/8	6 11/16	....	....
6	7/8	1 9/16	2 7/16	3 9/16	4 13/16	6 3/8	....	....	....
7	1 1/16	1 13/16	2 7/8	4 1/8	5 5/8	....	....	....	....
8	1 3/16	2 1/8	3 5/16	4 11/16	6 1/2	....	....	....	....
9	1 5/16	2 3/8	3 11/16	5 5/16	....	....	....	....	....
10	1 1/2	2 5/8	4 1/8	5 15/16	....	....	....	....	....
12	1 3/4	3 1/8	4 15/16	7 1/8	....	....	....	....	....
15	2 3/16	3 15/16	6 2/16	....	....	....	....	....	....
18	2 5/8	4 11/16	....	....	....	....	....	....	....
20	2 15/16	5 1/4	....	....	....	....	....	....	....

The greatest elevation must not exceed 6 ins., unless otherwise directed.

The elevation of outer rail on curves must necessarily be adapted to speed and other local conditions, with due regard to safety, comfort and economy of track maintenance, for all classes of trains.

The elevation on mountain grades should not exceed that required for 25 miles per hour.

The elevation of outer rail must not be continued beyond the tangent point, but should decrease uniformly along the easement curve from point of maximum curvature to tangent point.

To ascertain the elevation required at points on easement curves, trackmen are required to use a cord of standard length, the middle ordinate of which will be equal to the proper elevation, as follows:

Speed.	Length of cord.	Speed.	Length of cord.
20 miles per hour.....	31.74 ft.	40 miles per hour.....	63.48 ft.
25 " " "	39.68 "	45 " " "	71.42 "
30 " " "	47.61 "	60 " " "	79.35 "
35 " " "	55.55 "		

This method is applicable to all curves, and aids in maintaining true alinement, as all ordinates should be equal on full centered portions of curve, and ordinates must decrease uniformly on easement curves from full elevation to zero at tangent point. In using the cord to ascertain elevation, it should be stretched and firmly held at both ends against the inner face of rail on inside of curve. The middle ordinate will then be equal to the required elevation, and can be measured by a foot rule, or by attaching a short piece of graduated tape to the cord at its center.

All track levels must be tested by the engineer or roadmaster at the beginning of the working season, and the date of inspection recorded. Sluggish bubble tubes should be replaced.

TIE-PLATES.

The standard form of tie-plate will be used, with the standard 72-lb. rail section, in lieu of rail braces.

Tie-plates will be used whenever necessary to prevent tie cutting, generally on curves of 3° or over, depending upon local conditions. The widest margin must invariably be placed on the outer side of rail.

On tangents and light curves, but two spikes will be used in each plate. On sharper curves, three or four spikes will be used, when necessary. In cases of unusual difficulty in maintaining gage on mountain grades and sharp curves, before applying tie-plates the ties may be dapped to allow a suffi-

cient inclination to the rails to check any tendency of the rails to overturn, or to spread, observing due care to maintain gage.

In laying these plates, the line side of the tie is marked, and the plate put on, the other plate being then put on in its proper position by gaging it from the line plate with a gage rod, having lugs to fit the spike holes. The plates may be forced into the tie by a hydraulic press, or in the track by striking vertically with a paver's hammer, or with a short section of rail provided with cross bar handles. In putting plates on before the rails are laid, a wooden or metal block should be placed on the plate to distribute the blow. If put on after rails are laid, the rail may be lifted, the plate slipped in, an iron plate placed upon each projecting end of the plate, and these two plates struck simultaneously by two strikers with spike mauls, or, one end of the plate may be settled into the tie, and the free end then driven with a sledge, causing the flanges to plow their way through the wood under the rail.

RAIL BRACES.

Rail braces will be used when necessary with rail sections for which tie-plates are not provided, generally on curves of 4° and upwards. On curves of less degree, double spiking will usually be sufficient. The braces should always be placed in pairs on the opposite ends of the same tie.

FROGS AND SWITCHES.

Switches must be put in track in accordance with the standard plans. When temporary sidings are put in, the main line rails must not be cut, but short closure rails must be provided to fill the space between frog and the adjacent rail. Double spiked short rails should be used for this purpose.

BALLASTING.

All spikes should be driven down before ballast is distributed. Ballast should not be distributed until the roadbed is of full width and all unsuitable material removed. When material is unfit for use as ballast, it should be cleaned out from bottom of tie and used for widening the

banks. Where there is trouble in heaving, or wet spots, the material should be taken out to such depth and in such a manner as to insure perfect drainage. Care must be taken to avoid wasting ballast down the sides of slopes, or otherwise.

The depth of ballast will be determined in accordance with the local conditions, and the character and amount of ballast already in place, if any. In general, not less than 8 ins. of good material will be required under ties.

TAMPING.

Tamp the entire length of ties on new track. Special pains should be taken to insure thorough tamping from end of tie to 1 ft. inside of rail. On old track the center should be filled and lightly tamped.

Tamp joint and second ties thoroughly. Thorough tamping of the second tie from points is of equal importance with that required by the joint ties, and will prevent the formation of cracks starting from upper edge of splices by reducing the upward deflection of joints when a wheel is over the second tie.

Material for filling and ballasting must not be taken from slopes of embankments. When ballasting is completed, the track must be in perfect line, surface and gage, in accordance with the stakes furnished by the engineer.

BALLAST CROSS-SECTION.

Rock ballast should be filled in level with top of tie from center to 2 ft. outside of rail, slopes 1 to 1.

Gravel ballast must be finished to the standard cross-section, which is as follows:

At the center and for 1 ft. on each side thereof, the top of ballast will be even with the top of ties, and thence carried out with a straight uniform slope, passing 4 ins. above bottom of ties at ends, to a point $2\frac{1}{2}$ ft. outside of rail, thence to an intersection with the roadbed, with slopes of $1\frac{1}{2}$ to 1.

If material is used which is more or less impervious to water, the slopes should be carried to an intersection with roadbed on a line with bottom of ties at ends.

The practice of crowning the ballast above top of tie at center causes dusty track and rots the tie at the center and is

not permitted, except when absolutely required for drainage on account of the character of material used for ballasting.

SUPERVISION.

The engineer will furnish all necessary elevations, stakes and notes and will make frequent inspections during the progress of track laying in order to insure compliance with the specifications, promptly reporting defects to the roadmasters and superintendents.

V.

Bridges and Culverts.

INSPECTION.

The division engineers will make occasional examinations of the condition of all important bridges and culverts. In an emergency they will, on their own authority, report such repairs as they may deem necessary for safety, to the division superintendent for immediate attention. In other cases they will make their reports to the chief engineer, who will decide on the amount and character of the work to be done.

Great care must be taken by division engineers and supervisors of bridges and buildings, to whom the security of structures is intrusted, to make such inspections so thorough and the records thereof so complete as to convey definite and precise knowledge of the condition of each and every structure at the time of the last inspection.

There will be two regular inspections each year, as follows:

1. In January, by the supervisor of bridges for each division, of all truss and large trestle bridges.

2. In September, by the division engineers and supervisors of bridges, of all bridges, culverts, waterways, etc.

In addition the supervisors of bridges must at all times make such other inspections as may be necessary to insure safety.

The September inspection must be made with special reference to obtaining information for estimating the cost of renewals and repairs, and for the material required for the ensuing year.

The supervisors of bridges will forward the report of these

inspections, with an impression copy of the same, to the division superintendent for approval. Division superintendents will forward both copies to the division engineer.

The supervisor of bridges will make such further inspections as he finds necessary to keep thoroughly posted as to the conditions and safety of all bridges and culverts on his division.

Division superintendents will arrange to obtain the record of extreme high water at the time of each flood, or extraordinary freshet, at all bridges, culverts and openings.

Section foremen should be instructed to go over their sections at such times and take the measurement from top of tie to the extreme high-water mark, and report such measurements, giving the number of the bridge or opening, to the division superintendent.

Division superintendents will forward this information to the division engineers, who will retain copy and forward the information to the office of the chief engineer for record.

Supervisors of bridges will furnish the division superintendent monthly reports of all reports and renewals of bridges and culverts executed during the month. These reports will be forwarded to the division engineer, who will check same against the inspection requirements, for the purpose of insuring compliance with such requirements.

At the completion of the work, the supervisors of bridges will forward a report to the division superintendent showing all changes in the class of structure, details of construction and length, height and position of structures; also the cost of labor and material expended. This report will be forwarded to the division engineer for final record.

Following the September inspection, estimates of the cost of repairs, renewals and replacements recommended for the ensuing year will be prepared by the division supervisors and division engineers, which will be tabulated and forwarded through the office of the chief engineer.

The character and extent of renewals and improvements will be determined from this report. Descriptions and estimates will be given for permanent structures, wherever same appear desirable or economical.

This report will show the cost of necessary repairs recom-

mended for the ensuing year; the average annual cost of such repairs; the total cost of the structure upon which repairs are recommended, and also the total cost and annual interest upon permanent structures when such structures are recommended.

All changes, additions or expensive renewals of bridges, culverts or other important structures, shall be made only upon the properly approved plans and estimates of the chief engineer, who will make contracts for and superintend the work.

INSTRUCTIONS TO INSPECTORS.

Note books of inspection must be filled out at the structure after a careful examination has been made of each of the points itemized in the blanks, using, in cases where there are a number of spans in which defects are observed, a properly noted column for each span. When the spans are all in good condition, one column only need be used, but the number of spans should be noted.

Designate the separate spans of a bridge by numbering them in the direction of the bridge numbers on the division, and the separate bents or piers in same manner, commencing with abutment, bank-bent or sill as number one. Designate the truss as the right or left, locating points on it by numbering the panels in the same direction as the spans are numbered.

When wooden structures are four years old, such members as by their position are particularly liable to decay must be tested by boring, the holes to be plugged up as soon as the inspection is completed.

When making the regular inspections the inspectors will take a statement of the results of the last examination relative to such structures as required attention at that time, and in reporting on these structures, special notes must be made as to whether the repairs and recommendations of the previous examinations have been fully carried out or not, and whether the work is in accordance with the standard plans.

INSTRUCTIONS REGARDING INSPECTION REPORTS.

(Numbers and directions in these instructions correspond with numbers and abbreviations on report blanks.)

1. Does waterway require straightening, cleaning out or

enlarging above or below structure? Does structure afford ample waterway? Is riprap needed to maintain channel or protect roadway?

2. Note line and surface, also condition of rails, joints and fastenings on bridge and approaches. See that rails are braced on curves where necessary, and that track on approaches is firmly bedded, avoiding shock or jolt to train as it passes on to bridge.

3. Note any rotten, split or otherwise defective bridge ties, giving number, size and kind.

4. See if guard rails are in line and bolted or spiked down tight.

5. Note condition of caps and stringers, particularly at points where they bear against other members.

6. Note if plumb and batter posts are crooked, split or decayed, and if bents stand plumb.

7. See if trestle towers or bents are properly sway-braced, and all braces longitudinal and transverse are drawn up tight and have sufficient bolts or spikes to hold them properly.

8. Note particularly the condition of piles where they enter the ground or water. See that they stand properly.

9. Examine each pier and abutment as to joints, settlement, imperfect stones, cracks or other defects; note if work needs pointing up, or if cracks have opened since last pointed; make such measurements as will locate position of cracks, and note on sketch on back of report blank: Condition of riprap if any. Is riprap needed to prevent undermining? How much? Condition of pedestal stones, and whether bridge seat is clean and water drained off.

10. Note condition of culvert and retaining walls. See if they are yielding by settlement or bulging from the pressure of the embankment.

11. Condition of ring, or covering stone, of box or arch culverts.

12. Note condition of paving and riprap, and that same is so placed that it cannot be undermined by washing.

13. Does pipe drain need head or tail wall to protect embankment from washing? And does it clear itself of water?

14. Does timber box need to be replaced with masonry or

culvert pipe? If so, give dimensions required to give ample waterway, and give height from bottom of stream to rail.

15. See if bed plates and rollers are clean, and if the latter stand so as to move squarely back and forth with the truss. See if pedestal takes an even bearing on rollers. Examine anchor bolts.

16. Observe particularly the condition of wall plates where bolster rests upon them. Note any appearance of crushing or decay.

17. Note condition of bolsters and corbels. See if holes are bored through them where they cover the spaces between chord sticks, to prevent the collection of water, and if there is any indication of decay where they are in contact with chord.

18. Angle blocks and all cast-iron members such as chord-boxes, post shoes, etc., must be examined for cracks and for any indication of displacement by reason of daps splitting or timber crushing. A hole of $\frac{1}{4}$-in. in diameter, if drilled at the end of a crack, will frequently stop its extending farther.

19. Note particularly any appearance of opening of bottom chord joints. Wooden bridges over four years old should have gage blocks at all joints in the middle half of the span, made by fastening two planed and squared blocks 1×2 ins., 6 ins. long, to the chord sticks with screws, and scribing a fine line across both. Any movement of joints should be noted, giving location and amount, scribing a new line from the old one on the outside block across the inside block. See if clamp daps are shearing.

20. See that all chord and packing bolts are tight. Nuts on all bolts through guard rails, ties, stringers and floor beams must be secured in place by burring the thread of the bolt at two or three places with a center punch or cape chisel.

21. Note any signs of decay or crushing in packing blocks, and see that clamps and keys are in proper condition.

22. See if gib plates are distorted, or crushing into the chords; if they are, give their location and dimensions, number, size and spacing of rods passing through them. Give size of rods over threads.

23. Note condition of sides and roof of covered bridges or of chord and end post covering.

24. Notice particularly the connections between stringers and floor beams; see that connecting angles are not split, either in the angle or through in the line of the rivet holes. For wooden stringers, note condition as to soundness of bearings.

25. Notice particularly the connections between floor beams and trusses for evidence of imperfect bearing, or splitting of connecting angles. If suspended, notice if they are up tight against the post feet, or free to move.

26. Test equality of tension in tie bars by springing them. Look for any signs of distortion or crookedness in bars of end panels of bottom chords. Howe truss rods, counter lateral and vibration rods must never be allowed to hang loose. They must not be adjusted while a load is on the bridge. They should be tightened enough to give close and even bearings, but must not be overstrained, as unnecessary strains are put on compression members if too much power is used in adjusting tension members. See that the center line of all tension members is the same as the line of strain.

27. Examine carefully, especially at the joints.

28. See if posts, lateral struts and top chords are straight and free from twists. On wooden bridges, see if braces are up in place, taking a square bearing at ends, and note if any warping is evident. Note their condition as to soundness.

29. Examine all lateral connections, and see that lateral tension members are straight. Examine bracing in iron trestles.

30. Make particular examination of all hangers, testing each nut to see that it is tight. A streak of white paint down across nut and bearing will indicate any movement. These nuts should be screwed up tight and secured by burring the thread of bolt and nut at two or three points with a center punch or cape chisel.

31. Note any pins which indicate the movement of any of the members coupling on them, or that have loose nuts. All pins and nuts should have a streak of white paint across nut and pin end.

32. All field driven rivets in floor beams and stringer con-

nections should be lightly sounded to see that they are tight. Also lateral connection rivets in riveted trusses, and any intersection or other rivets which indicate by rust streaks, or otherwise, that there is movement at that point.

33. Note if there are any members, such as closed columns, pedestals, etc., which catch and retain water by reason of not having proper drain holes.

34. Note carefully the line of each truss by the top chord and by points on the floor beams equidistant from the center of the posts. Also note the camber by the top and bottom chords, whether it is true and uniform or irregular.

35. Look for loose rods, hangers, loose braces, unequal sized timbers and other defects which require adjusting in order that each of the different parts may have proper bearings and carry its proper part of the load.

36. Note any undue vibration of the structure under live load.

37. Note excessive deflection of the structure under live load, seeing if the two trusses have the same deflection.

38. See if any rust spots are apparent under the paint. Note if structure needs repairing. Iron bridge work should be scraped and repainted as often as necessary to preserve from rusting.

39. Note such wooden structures as require barrels to add to their safety, giving number required. State condition of such barrels as may be in position. On all bridges of such magnitude as to require a watchman, there should be a foot plank between the rails securely fastened to the ties to facilitate crossing the bridge quickly in emergencies, such as fire or danger to trains. Note if ladders, either fixed or portable, are required for the safety of the structure or to facilitate inspection.

40. See if material, driftwood, weeds, grass or other rubbish is properly removed and burned, or otherwise disposed of.

LIST OF ABBREVIATIONS FOR CLASS OF STRUCTURES.

W.B.—Wooden or timber box culvert.
S. B.—Stone box culvert.
S. A.—Stone arch culvert.
T. P.—Tile culvert pipe.
C. P.—Cast culvert pipe.
B. D.—Blind drain.
W.C.—Wall culvert.
P. B.—Pile bridge.
P. C.—Pile culvert.
T. B.—Trestle bridge.
H. T.—Howe truss.
C. T.—Combination truss.
I. T.—Iron truss.
D. S.—Draw span.
P. G.—Plate girder.

ERECTION OF STEEL BRIDGES.

GENERAL.—Engineers, inspectors and contractors are expected to make themselves thoroughly familiar with the general and special specifications governing the work.

All material received must be carefully checked, recorded and reported immediately upon receipt of same, in accordance with the rules. Shortages should be reported immediately. Material received should be checked against complete bill of material, and every effort made to avoid delay to the progress of the work, by failure to receive material, including false work, tools, etc., etc.

The engineer in charge must cause to be kept an accurate record of the cost of the work, including material and labor, keeping separately each class of work, such as rigging up, unloading, repairing, raising, fitting, riveting, cleaning, painting, framing, bolting, contractors' pay roll, character of plant, framing and erecting false work, and removal of same. A diary must be kept containing dates of commencing and completing different classes of work, and all other general information of value. A record, or copies of all orders, on instructions, issued or received during the progress of the work, and the daily force account should also be kept.

The engineer in charge must check all distances and elevations on plans, before laying out the work, and will be held responsible for any errors that may arise, through neglect on the part of himself or assistants, properly to verify and recheck, plans, points and elevations, given for the erection of the structure. Distances between centers and elevations of finished tops of masonry are especially important, and should be rechecked as often as may be necessary, in order absolutely to insure against errors. The sum of the heights of the component parts forming the structure should be carefully checked against the total finished height, above assumed datum, to base of rail. The sum of all detail lengths must also be checked, with equal care, against the total length from the fixed initial point.

Insure that the material shall not be injured, nor dangerously strained during the operation of loading, unloading or

handling same. All defects in workmanship or material must be remedied as soon as detected. A thorough inspection must be made for defects in painting, cleaning, reaming, spots of shrivelled oil or paint, chips, burrs, sharp edges and black or rusty spots on steel, scale, cinders and scratches, particularly in joints and around rivet heads, brush hairs, or other foreign matter covered over with paint or oil; all such defects shall be remedied immediately, and noted in detail, to provide full information, in case of claims for extra compensation.

Slight bends in members shall not be straightened unless strictly necessary, on account of the danger of overstraining connections and rivets. Connection plates, if slightly bent or twisted, shall be straightened cold; if bent so sharply as to require heating, the whole piece thus heated shall be subsequently annealed. All shop rivets, or any piece of member thus straightened, shall be properly tested.

Particular care will be taken to insure free expansion and contraction, wherever provided for in plans. Any departure in dimensions, amount of camber or otherwise, of material received, from plans and specifications, must be noted and reported immediately.

All machine-fitted bolts shall be perfectly tight, and should be burred or otherwise checked to prevent nuts from becoming loose, and no unfilled rivet or bolt holes should be left in any part of the structure.

FITTING AND CHIPPING.—The material must be assembled in accordance with the match marks, and no interchange of pieces must be made, unless absolutely necessary in order to avoid chipping and fitting, or serious delay.

Fitting and riveting of connections (especially angles) in cases where pieces are short or full, must be done in such a manner that the metal is not unduly strained, or cracks caused.

Dishonest or incompetent workmen frequently fill cracks with paint, putty, cinders, dirt, oil or fillings, for the purpose of deception. A close inspection must be made for this.

Wooden rams or malls must be used in forcing members to position, in order to protect metal from injury or shocks.

Chipping of rivets, angle flanges, and edges of plates, must

be done without breaking out metal. Chipped edges must be finished off with a file, and all concave corners must be rounded off. Chipping with a sledge will only be permitted in exceptional cases, and must be done without leaving fractured edges.

RIVETING.—In driving rivets, the dolly and die should be placed directly opposite each other, at right angles to the riveted surface, to insure straight driving. Rivets must be driven while at an orange heat, and no burnt rivets should be used.

After riveting, each rivet must be tapped with a hammer to insure that they are tight, and the heads must be well formed, concentric with center of rivet, and closely fitted against the riveted surface.

Defective rivets can usually be detected by their color, or by sound when tapped with a hammer, and all loose or burnt rivets must be immediately cut out and replaced.

In cutting out rivets be careful to ascertain that other rivets in proximity have not been loosened.

Tightening up, recupping or calking old rivets will not be tolerated, except that occasional recupping of shop rivets do not form part of important connections, or do not directly transmit stresses.

Countersunk rivets must be inspected after chipping heads, and no unnecessary chipping should be permitted.

PAINTING.—The specifications under the head of cleaning, oiling and painting must be strictly carried out.

An accurate account should be kept of the quantities and proportions used, of pigments, oils and other ingredients, and the quantities by weight or fluid measure, of the resulting mixtures, ascertained. A record should be kept of the quantity of paint applied, of each coat, and its proportion ascertained to area or weight of material covered.

Paint should be thoroughly worked in all corners of joints, and narrow openings, covering edges and sealing up all lines of contact between parts.

Unless otherwise specified, the ingredients and proportions of the mixture, for the three coats, shall be as follows:

First Coat.—30 lbs. pure lead to 1 gallon pure boiled linseed oil, 1-3 pint pure turpentine.

Second Coat.—25 lbs. pure lead to 1 gallon pure boiled linseed oil, 1 pint pure turpentine, lampblack, quantity not to exceed 12 ounces.

Third Coat.—15 lbs. dry pigment, Cleveland Ironclad, purple band No. 3, to 1 gallon of pure boiled linseed oil.

VI.

Accounting and Miscellaneous.

BILLS.

Every official incurring indebtedness on account of the company will request that bills covering the same be rendered promptly; upon receiving such bills they will be carefully examined, and, if found correct, so certified in ink by the official, who will sign his full name and title; they will then be forwarded to the assistant engineer, who, after approving the same, will forward them to the division engineer for voucher.

Bills should state all the facts as clearly as the nature of the case will permit, giving all items, quantities, prices and dates in full; if bill as rendered does not give all information necessary to a proper understanding of the transaction, the certifying official should add sufficient explanation to make it fully understood.

All bills should reach the division engineer's office not later than the seventh day of the month, and such record kept of them by certifying officials as to preclude the possibility of their certifying a duplicate bill for the same account.

Bills covering purchases by the purchasing agent, or shipments from stock, will be forwarded by the general storekeeper, or division storekeepers, to the engineer in charge of the work, who will write the distribution on face of bill, certify to the receipt of the material and return bills promptly.

VOUCHERS.

All vouchers will be made in division engineer's offices, certified by them, and forwarded promptly to the chief engineer. They should be forwarded daily as made up, and should all reach the chief engineer's office by the sixteenth of the month.

An impression copy should be retained of all vouchers for-

warded, and they should be numbered consecutively, commencing with No. 1 for the first January voucher each year.

CASH EXPENDITURES.

Officials supplied with company funds should understand that the money is only to be used to make small payments for supplies in the field, or other expenditures for which circumstances make it necessary to pay cash. Wherever possible, bills should be certified and forwarded for voucher in the usual manner.

For all cash payments, receipts on form 104 should be taken, giving the residence of signer and date of payment. If for supplies, the receipt must give different items in detail; when for board or lodgings, the exact time for which charge is made, promptly at close of month, with list of same accompanying and name of the individual boarded or lodged.

These receipts must be sent in to assistant engineer and, after examination, forwarded to division engineer for voucher.

Officials must be careful to observe the limitations placed upon making cash payments, as it is found there is a tendency to make unnecessary payments in this manner, instead of forwarding bills for voucher and payment by the treasurer.

TIME RETURNS. (FORM 102.)

Time returns will be made out by each official in charge of a party, and, after being certified, forwarded to the assistant engineer in charge of the work in time to reach his office on the first day of the month. After being approved they will be forwarded to the division engineer so as to reach his office by the third of the month. This should be written in copying ink, and an impression copy retained by the assistant engineer.

The name and occupation of every employee will be returned on the time return, and when an employee has not worked a full month, the days actually worked must be shown.

Particular care must be taken to spell each man's name correctly on the return, and to write the same clearly; neglect to do this is inexcusable.

When time made by employees is omitted from return of

current month, it will be entered on succeeding month's roll with notation showing from what month's roll it was omitted. All possible care must be exercised to prevent such omissions.

Time of men who are paid a monthly rate will be stated in months or fractional parts thereof, using actual calendar days of the month in which the labor is performed, as 28, 29, 30 or 31, as the case may be; time of employees paid a daily rate will be stated in days and hours.

For gangs of laborers and section men, time books must be kept and sent in at end of month as prescribed for time returns.

PAY ROLLS. (FORM 1338.)

Pay rolls will be made up from time returns and time books in the division engineer's office, and three impression copies taken, one to be retained, and two to accompany the rolls, which will be forwarded to the chief engineer not later than the fifth of the month.

Time returns and time books will be sent to the chief engineer with the rolls; when the latter are audited, the returns and books will be sent back to the division engineer for file.

In forwarding time returns and pay rolls they will be folded, not rolled.

TIME CERTIFICATES. (FORM 306.)

Employees leaving the service of the company should be paid in full at time of leaving, or as soon thereafter as practicable. For this purpose an order for time certificate (form 807) will be given the employee; also an identification card (form 1290.) On presentation of these, time certificate will be issued by the assistant engineer or division engineer. If more convenient, the order for time certificate may be sent by letter or telegraph, and the time certificate sent to an official of this company for delivery, upon proper identification.

When an employee has been paid by time certificate (which will only be issued to men leaving the service, his name will appear on time return in usual manner, with the notation, "certificate given," and number of same. Parties issuing time certificates will be held responsible for their correctness, and for the proper notation being made on time return. Any over-

payment will be charged to them. Before the returns are forwarded the time certificate stubs should be carefully checked with same.

Be careful and see that the month in which service is performed is always correctly stated; if certificate be given for omitted time in one month, to appear on pay rolls for another month, note the fact prominently in red ink on the face of the check.

Time certificates cannot be issued after time returns have been forwarded, except by authority of division engineer, and after pay rolls have been forwarded, only by authority of chief engineer.

DEDUCTIONS FROM PAY ROLLS.

The Northern Pacific Beneficial Association Hospital dues must be deducted from all employees (except Chinese) on the following monthly basis:

Men receiving $25, or more, and less than $100, per month.....	$0.50
Men receiving $100, or more, and less than $200, per month.....	1 00
Men receiving $200, or more, per month.....	2.00

In consideration of the Association assuming risk of accident and sickness from the time men enter employ of the company, their first earnings are for the benefit of the Association, up to the amount of monthly dues, except in cases where the employee is indebted to the company. (See rule 27.)

In every case in which deduction is not made in favor of the Northern Pacific Beneficial Association for hospital dues, the reason will be stated on the roll; when the name of an employee appears on two or more rolls, deduction will be made but once and reference given to the number of the roll and line wherever the name appears again.

Other deductions will be made in accordance with the following instructions:

Amounts due N. P. Ry. Co. will be deducted from pay rolls; no orders will be required, and deductions of this kind will take precedence over all others.

Deductions will be made for board from section and other laborers boarding in section houses, boarding cars or boarding camps; it will not be necessary to take orders. Orders should, however, be taken for all board deductions from other employees.

When in the judgment of the superintendent, engineer or other officer in charge, it is necessary or desirable to protect parties who supply clothing or tobacco to employees on construction or work trains, deductions may be made from same when authorized by employee in writing; no such deductions will be made, however, except upon the written order of the employee.

Premiums due on accident policies will be deducted from pay roll when authorized by auditor of disbursements.

In making deductions on orders as authorized above, care should be exercised to conform strictly to the orders; an order authorizing a deduction from a particular month's wages will not be considered as authority for deduction of amount, or any portion of same, from wages earned in any month other than that specified in the order.

Orders will not be honored to an amount greater than the wages earned during the period mentioned in the order, and the order must be surrendered to the company before any deductions can be made thereon, either for the full amount of the order or a portion only.

When orders, except as authorized herein, are presented, they should be declined, as the company will not do a collecting business for the public.

Orders for deductions made should be sent to auditor of disbursements with pay rolls, and any deduction made other than as authorized herein, or for which proper orders are not received by auditor of disbursements (except in cases in which it is herein provided that orders are not required), will be disallowed.

Pay rolls will show to whom deductions from each employee are payable, and a deduction roll will be made containing name, address and amount due each party to whom deductions are payable, a separate sheet being made for amounts due Northern Pacific Beneficial Association, accident insurance companies and N. P. Ry. Co.

ASSIGNMENT OF WAGES.

Assignments will not be honored unless made for full amount due.

When a party claims to hold an assignment of wages and notifies the officers, under whom the assignor is employed, the holder of the assignment will be required to produce it; if found good in law, notation should be made in ink on pay roll, opposite name of assigning employee, in column provided for receipt, as follows: "Assigned to ————," giving name of assignee, and date of presentation of assignment; but no deduction will be made on pay roll. If assignment is presented before pay roll is prepared, a record should be made and proper notation made on pay roll when prepared; if presented after pay roll has been forwarded, the auditor of disbursements should be advised by wire. The treasurer must be notified by wire of every assignment as soon as presented.

After an assignment is made, the assigning employee has no further interest in the wages thus assigned, so far as this company is concerned, and payment will be made to assignee only; and to him only upon surrender of assignment to paying officer, who, upon payment thereof, will take assignee's receipt and attach assignment thereto.

Assignee will receipt thus: "John Smith, by Wm. Jones, assignee," and not individually.

GARNISHMENTS.

When services of garnishment or attachment is made on an officer, agent or employee of the company, he should at once telegraph the treasurer, division counsel and division engineer, stating the nature of the case and giving the name of the plaintiff and defendant, and also the occupation and location of the latter. He should forward papers served by first train mail to the division counsel for the district in which the action is brought.

CONTRACTORS' ESTIMATES.

Promptly at the close of the month each resident engineer will make up on form 94 detailed estimates, by stations, of all work done by contractors. They will be written in copying ink, and forwarded in duplicate to the assistant engineer, who, after checking and approving, will consolidate the same on forms 107 and 108, and forward one copy with 107 and 108 to the division engineer for voucher.

Forms 107 and 108 will be forwarded to the chief engineer with the voucher covering the estimate.

As contractors' estimates are generally payable on the twentieth of the month, it is absolutely necessary they should reach the chief engineer not later than the tenth, and, to secure this, prompt and accurate work by all concerned is necessary.

Separate forms 94, 107 and 108 must be made for the work of different contractors.

No information will be given to contractors or sub-contractors in reference to their estimates until the same shall have been approved by the assistant engineer.

APPROXIMATE ESTIMATE OF EXPENDITURES. (FORM 112.)

On the first day of every month, each assistant engineer will telegraph his division engineer an approximate estimate of the expenditures on his work in the preceding month. Give amounts to nearest hundred dollars, and after this manner, viz.:

Northern Pacific Bills and Traffic Charges	$1,200
Pay Rolls	1,000
Bills	5,600
Estimates	4,800
Total	$12,600

Note.—Contractors' estimates should include retained percentage, if any, and if more than one contractor on the work, give estimate of each separately. Include all bills sent in to division engineer for voucher in preceding month. Give any extraordinary expenditure as a separate item.

The approximate estimate of assistant engineers will, after being checked by the division engineer, be telegraphed to the chief engineer not later than the third of the month, each piece of work being given separately.

DISTRIBUTION.

All bills, pay rolls and estimates must be distributed by the certifying official before being forwarded, by notation on face of bills, and by a memorandum accompanying estimates and pay rolls. Distribution to buildings must show the particular structures and their location.

Engineering expenses are not to be so distributed, the object being to keep record of the labor and material expended directly upon each building. Treat in above manner stations, section houses, freight houses, water tanks, pump houses, turntables, engine houses, important bridges, etc.

When voucher is prepared, the distribution will be condensed on face of voucher. Use abbreviations or write out in full, instead of numerals, when indicating the distributions on voucher. The following is the established construction distribution:

Engineering Expenses.

1.—SALARIES AND WAGES.

To this account should be charged the salaries and wages of all persons employed in engineers' service, including clerks, janitors, teamsters and cooks.

2.—OTHER ENGINEERING EXPENSES.

To this account will be charged the cost and repairs of field, office and pocket instruments, drawing boards, blueprint apparatus, office furniture, stationery boxes, tents, temporary quarters for engineers, camp equipage, cooking utensils, stoves, cost or hire of animals and vehicles; provisions and forage for men and animals, including board, hotel bills, traveling expenses, stable bills; rent, heating, lighting, cleaning and repairing engineers' offices; stationery and other contingent expenses of engineers.

LAND.

3.—RIGHT OF WAY AND STATION GROUNDS.

To this account should be charged the cost of land acquired for roadbed (of necessary width conformity to depth and slopes of excavations and embankments), station and terminal grounds; also the cost of land purchased for ingress or egress to and from station grounds; salaries and expenses of counsel, right-of-way agent, and of engineers and assistants when especially engaged upon such matters; stakes used to denote right-of-way limits; expenses of appraisals, or of jur-

ies, commissioners or arbitrators in condemnation cases, cost of removal of buildings when upon right-of-way, station or terminal grounds, but not included in property purchased; stationery supplied right-of-way agent, engineers and assistants, engineers' instruments, etc., when used for such purposes; commissions paid outside parties for purchase of properties for these purposes; cost of plats, abstracts, notarial fees, recording deeds, etc.

Note particularly account No. 4 as regards the cost of property purchased, but not required for the operation of the road.

4.—REAL ESTATE.

To this account should be charged the cost of all land purchased by the railway in excess of that actually required for roadbed, station, or terminal grounds, or other specific purpose, including all expenses incurred in connection with such purpose as enumerated in account No. 3, "Right of Way and Station Grounds." A portion of the cost of land purchased outside right-of-way for borrow pits or waste banks should be charged to this account.

Note.—The amount to be charged to Real Estate should be an estimate of the salable value of said borrow pits or waste banks after completion of the road.

ROADWAY.

5.—CLEARING AND GRUBBING.

To this account should be charged the cost of clearing right-of-way, station grounds or otherwise, and grubbing, as required by specifications.

6.—GRADING.

To this account should be charged the cost of grading roadbed and station grounds whether excavation or embankments; dressing slopes of cuts and fills; reconstructing pikes or roads; ditching roadbed; berme ditches; cost of material taken from borrow pits, haul if allowed; rent of equipment used in hauling material; amounts paid for privilege of borrowing material or making waste banks outside of company's right-of-way or station grounds; ditches for water ways not specially re-

quired by right-of-way agreement, in which case cost would be properly chargeable to Account No. 3. This account also includes retaining walls and other masonry or rip-rap for the protection of embankments, cuts, and slopes; cribbing or bulkheading built to protect the tracks or embankments along the seashore or banks of lakes and streams, including the cost of cribs, breakwaters, wing dams, or other devices constructed to change the direction of the current of a stream to prevent the washing out of the bank.

7.—TUNNELS.

To this account should be charged the cost of tunneling, including such timber as may be used for centering, packing, etc.; cost of stone, brick, cement, sand, lime, salt, piles, timber, spikes, nails, braces, concrete, etc., used in the construction or lining of the same; cost of labor preparing or securing the same scaffolding, cofferdams, and pneumatic caissons; cost of soundings and machinery, pumps, engines, etc., used for such work. This account does not include grading or surfacing the roadbed, or cost of the track through the tunnel.

8.—BRIDGES, TRESTLES AND CULVERTS.

To this account should be charged the cost of all bridges and trestles erected to carry tracks over streams, ravines, streets, or other railroads, and culverts, both substructure and superstructure, including fire protection. This account should include abutments, piers, pier filling, supports, draw and pier protection, machinery to operate drawbridges, masonry ends and wing walls for culverts, cost of inspection of bridge material either at shop or site of structure, cost of tests, cost of wing dams, cribs, or ice-breakers for the purpose of regulating the current of a stream or breaking up ice jams before reaching a bridge; also labor and material used in painting structure.

In case "false work" is furnished by the company for erection of bridge superstructure, the cost of same should be charged to this account, and when removed the value of the material removed should be credited to this account and charged to the account benefited.

TRACK.

9.—TIES.

To this account should be charged the cost of all cross, switch, bridge, and other ties laid in the main track or tracks, sidings, spurs, gravel and repair tracks; in tunnels, depots, shop and other yards, shops and other buildings, etc.; on turn-tables, wharves, piers, track scales, inclines, bridges, trestles and culverts to and from coal chutes, coal pockets, fuel and water stations, etc.; also the cost of inspection, loading, unloading, and any process of preservation.

10.—RAILS.

To this account should be charged the cost of rails laid in the main track or tracks, sidings, spurs, gravel and repair tracks; in tunnels, depots, shop and other yards, shops and other buildings, etc.; on turn-tables, wharves, piers, track scales, inclines, bridges, trestles and culverts to and from coal chutes, coal pockets, fuel and water stations, etc.; also the cost of inspection, loading and unloading.

11.—TRACK FASTENINGS.

To this account should be charged the cost of spikes used for laying rails, and of fish and tie-plates, splice or angle bars, chairs, rail braces, bolts, nuts, nut locks or washers used in connection with same; also cost of inspection, loading and unloading.

12.—FROGS AND SWITCHES.

To this account should be charged the cost of all frogs, switches and switch material, including switch stands (throw or lever), frog guard rails, crossing frogs and timbers, bolts, etc., used in foundations or base for same.

13.—TRACK LAYING AND SURFACING.

To this account should be charged the cost of distributing, laying, spacing and lining ties; cost of laying, spiking and jointing rails, surfacing and lining track, including the adjustment of rail to proper elevation, and labor of placing frogs and switches; cost of track tools, including shovels, picks, track jacks, crowbars, levers, spiking mauls, gages and wrenches;

cost of putting in ballast; service of engines, cars and crews distributing track material, and rental of such equipment.

14.—BALLAST.

To this account should be charged the cost of all ballast, whether of broken stone, slag, gravel, other material especially provided for this purpose; also the expense of loading, haulin, unloading alongside of track, and rent of equipment.

STRUCTURES.

15.—STATION BUILDINGS AND FIXTURES.

To this account should be charged the cost of all material and labor expended on station buildings and out-houses in connection therewith, including cost of platforms, sidewalks, excavation, foundation, drainage, water, gas and sewer pipes and connections, steam-heating apparatus, stoves, electric light and power fixtures, including wiring for same, grading and putting ground in order after building has been finished; electric bells, elevators, and all other material, furniture, or fixtures used to complete the building; wells for water supply of stations; also salaries and expenses of architects.

Note.—This account should include the cost of similar buildings on docks, wharves and piers, when used for station purposes.

16.—ENGINE HOUSES AND TURN-TABLES.

To this account should be charged the cost of all round houses (including cinder and drop pits), and turn-tables, heating, lighting and power plants, platforms, sidewalks and outhouses in connection therewith.

This account should include amounts paid when erected by contract, labor and material when built by company, preparing grounds before and clearing up same after construction, foundations, painting, excavation for and lining turntable pit, and of cinder or drop pits inside or outside of round houses; foundation for turn-table; loading, unloading and placing turn-table in position; levers, stops and machinery for operating turn-table; sewerage systems, connection with water supply system and wells. This account does not include

the cost of tracks laid in connection with round houses or turntables.

17.—ENGINE AND CAR SHOPS.

To this account should be charged the cost of all buildings to be used as shops (including transfer tables); heating, lighting and power plants, platforms, sidewalks and outhouses in connection therewith; oil houses, sand houses, store houses for company's material, scrap bins, etc.

This account should also include amounts paid when erected by contract, labor and material when erected by company, preparing grounds before and clearing up same after construction; foundations, painting, sewerage systems, connection with water supply system and wells. This account does not include the cost of tracks laid in connection with these buildings.

18.—SHOP MACHINERY AND TOOLS.

To this account should be charged the cost of all new machinery and additional tools placed in any of the shops, including foundation for same; loading, unloading and placing machinery in position. It must not include any machinery or tools purchased to take the place of those that have been worn out or destroyed.

19.—WATER STATIONS.

To this account should be charged the cost of the material and labor expended in the construction of water stations for the purpose of supplying locomotives with water, including cost of windmills, pumps, boilers, pump-houses, tanks, tubs, tank foundations, track foundations, track tanks or troughs, engines and all fixtures and pipes, standpipes or penstocks and connections; wells, dams, and reservoirs or cisterns; also tools used in the work. This account must not include waterworks, wells, etc., exclusively for supply of stations, hotels, tenements or section houses, which should be charged to the appropriate accounts.

20.—FUEL STATIONS.

To this account should be charged amounts paid under contract for, or the cost of all labor and material expended in the

construction of coal platforms, coal sheds, coal pocket chutes, woodsheds, and racks, and all machinery or appliances necessary to equip them for service. This account includes inclines at fuel stations (except the cost of track laid thereon), tipple cars, buckets, cranes for handling same, elevating machinery, gasoline or other engines for operating same, dumping machinery, all appliances for weighing coal in pockets and opening coal pockets.

21.—FENCING RIGHT-OF-WAY.

To this account should be charged the cost of all material and labor used in constructing board, wire, rail, hedge, stone, or other fences along the right-of-way or limits of roadbed; but no charge should be made to this account for fences constructed around stock yards, fuel stations, station grounds, shops, and on other properties outside of right-of-way, which should be charged to their appropriate accounts.

22.—SNOW FENCES AND SNOW STRUCTURES.

To this account should be charged the cost of all structures erected exclusively to protect road or buildings from snow.

23.—STOCK YARDS.

To this account should be charged the cost of all labor and material expended on stock yards, including facilities for feeding, watering and weighing.

24.—CROSSINGS, CATTLEGUARDS AND SIGNS.

To this account should be charged the cost of all labor and material used in constructing farm, country road or street crossings at grade; overhead bridges, cattleguards and wings —and all track signs, crossing gates and watch-houses at crossings.

25.—INTERLOCKING OR SIGNAL APPARATUS.

To this account should be charged the cost of interlocking or signal apparatus complete, when built by contract. If built by the railway company, the cost of labor and materials, including all levers, racks, wires, pulleys, semaphores, semaphore signals, ground signals, posts, material in box troughs,

and other fixtures, tower, foundation for same, and all other work necessary to complete it.

26.—DOCKS, WHARVES AND COAL BUNKERS.

To this account should be charged the entire cost of docks, wharves, ferry or other landings, inclines to transfer steamers, and coal bunkers and machinery; including grounds and riparian rights, dredging of slips, piling, filling cribs, pile protection, building cofferdams, pumping or bailing water, masonry walls or filling, etc., and all expenses incurred in the construction of these structures, except the cost of tracks and buildings thereon.

27.—TRANSFER BOATS AND BARGES.

To this account will be charged the cost of boats and barges. Renewals, repairs and operating expenses of boats in construction service are not chargeable to this account, but will be charged to the accounts benefited by the service, this account being designed to represent the cost of the property only.

28.—SECTION AND TOOL HOUSES.

To this account should be charged the cost of all labor and material expended on all buildings for use of track and bridge men, including buildings for storing and protecting hand and push cars, tools, etc.

29.—MISCELLANEOUS STRUCTURES.

To this account should be charged the cost of structures of every character, including cost of materials, labor, and all incidental expenses connected therewith, which are permanent or a betterment to the property and enter into the cost of road, and which are not otherwise herein particularly referred to, and for which no account has been provided; the object being to designate one general classification, to which may be charged the cost of all minor structures, and in this way avoid increasing the number of general accounts.

30.—TELEGRAPH LINES.

To this account should be charged the cost of newly constructed telegraph and telephone lines; including poles, wires, billets, insulators, instruments, and all other materials

used, also labor employed in the construction work, and cost of all tools used.

MISCELLANEOUS.

31.—TRANSPORTATION CHARGES.

To this account should be charged local freight, passenger and express charges over the Northern Pacific Railway and branches.

32.—OPERATING EXPENSES AND EARNINGS.

To this account should be charged all expenses, not herein designated to be charged to other accounts, for transporting construction material over road being constructed and for rental of equipment; also expenses for operating road for traffic while in charge of construction department, including payments for personal injury, stock killed or injured, or other damage caused by operating for traffic. This account will be credited with amounts received for transportation of such traffic.

33.—CONSTRUCTION EQUIPMENT.

To this account should be charged cost of all equipment for construction purposes, including steam shovels, pile drivers, stone derricks, stone crushers, iron, hand, push and velocipede cars and tunnel machinery, but exclusive of boats. Renewal, repairs and expenses are not chargeable to this account.

34.—GENERAL EXPENSES.

To this account should be charged expenses of incorporation and all contingent expenses, which are not proper charges to engineering; such as taxes, printing and engraving bonds, etc.

35.—INTEREST AND DISCOUNT.

To this account should be charged construction interest, discount on securities sold, interest on loans effected and on notes issued for construction purposes or overdue payments to contractors or other creditors, and discount, interest and exchange on other commercial paper issued for a similar purpose. Premium realized from sale of bonds, stock, or other securities should be credited to this account. Discount or premium real-

ized from sale of bonds, stock or other securities for a specific work should be applied to such work.

TRACK LAYING REPORTS. (FORM 19.)

The number of feet of main track laid every day must be telegraphed to the chief engineer and division engineer in the following manner:

"Gallatin—Butte Division, main track laid Jan. 16, 1890, from station 626 to station 640, fourteen hundred feet."

A daily record of all track laid must be carefully kept on form 19, with every blank properly filled in. This report will be forwarded to division engineer by first train, who, after checking and making record of same, will forward to chief engineer.

INSTRUMENT REPORTS. (FORM 11.)

All persons in charge of instruments, live stock, tents, etc., will make a monthly report of same on form 11, following printed instructions on blank. These reports will be written in copying ink and forwarded to assistant engineer, who will forward all for his work, in one package, to division engineer. After being checked in division engineer's office, an impression copy will be taken and all forwarded in one package to chief engineer.

Instruments which become unfit for service should be forwarded to Chief Engineer, with a card attached, stating the defects in full.

Instruments must be properly cared for, and any damage resulting from negligence will be charged to the party at fault. Surplus instruments should be sent in to division engineer.

REQUISITIONS. (FORM 1018.)

All requisitions will be made on form 1018, numbered and an impression copy retained. Assistant engineers will make requisition through the division engineer.

An impression copy of the requisitions made by division engineer will be sent to assistant engineer to advise him as to what material has been ordered for his work, and to enable him to check the same upon receipt.

Purchases of subsistence stores and camp equipment will be

made by assistant engineers under the supervision of the division engineer.

For all other articles, requisitions must be made as above specified, except in cases of emergency to avoid delay to work, when material may be ordered by wire, such orders being confirmed at once by requisition on form 1018, with notation "confirming telegram of this date." Should urgency be so great as to require immediate local purchase, authority for such purchase must be obtained by wire.

RECEIPT OF MATERIAL AND DISTRIBUTION RECORD.

All material must be carefully checked with invoice immediately upon receipt, and a record of it entered in the "Material Book" (form 170), showing date received, car initials and number, way bill number, quantity and description of material, name of shipper, date of invoice and amount, date that the invoice is certified and returned, amount of traffic charges, and date expense bill is certified and handed back to agent. Any shortages must be reported by letter accompanying the invoice. A smaller book or blotter will be used in entering receipt of the material, from which the Material Book will be posted.

A distribution record (form 171) will be kept, containing a complete record of construction cost in proper numerical order, including both labor and material, under the accounts numbered 1 to 35.

In this record will be entered the following:

1.—The bills of material required for each special structure or bridge, and all general construction items of rails, cross ties, angle bars, bolts, fencing, etc., not included in special bills of material.

2.—The number of the requisition covering each item of material.

3.—The partial or complete receipts of material applying on such requisition.

4.—The reference to the page of the Material Book (form 170) from which such receipts are posted.

5.—The cost of the material received as ascertained and posted from the invoices of same.

Enter under proper accounts, engineering expenses, expenditures for right-of-way, real estate, and all other expenditures that go to make up the complete cost of the work.

Accounts should be posted daily, checking complete receipts of each item in red ink. Partial receipts should be entered under head of remarks, noting page number of Material Book and amount of invoice, until completed and properly counterchecked.

This record must show at all times the exact relation between the requirements of the bill of material and the receipts to date, as this information is most important.

At the conclusion of the work forward the material and distribution records to the division engineer, who will furnish to the chief engineer a complete abstract of cost of each special structure, including large bridges, containing cost of each class of labor or material, but omitting itemized details of same.

Where, under the terms of contract, contractors are required to care for material, the records will be kept in precisely the same manner. Material clerks are required to give contractors every assistance in caring for material, and full information at any time as to the purpose for which any material is intended, and will see that no material is diverted from the purpose for which it was intended, without authority of assistant engineer.

All material must be unloaded promptly, and no material will be borrowed, loaned or sold except by authority of chief engineer.

TRANSFER OF MATERIAL TO OPERATING DEPARTMENT.

When work on branch lines, or on special improvements is finished, all material left over will be inventoried by the engineer in charge, and loaded and shipped to division store, or otherwise, as directed. This inventory (form 7) must show in detail location, quantity, description and percentage of value as compared with new material of like kind. It should be forwarded promptly to the division engineer, thence through the office of the chief engineer to the general storekeeper, who will arrange to give the work proper credit.

FREIGHT AND EXPRESS.

Freight and express agents, at stations where material is being received, will be instructed to deliver it upon expense bills, being certified to in following manner:

Received.....1....

Signed.....

Assistant Engineer (or Material Clerk or other official).

Here insert division or branch.

Care should be taken to note, on face of expense bills, any shortage or damage, and the agent should be immediately notified in writing.

Freight or express charges should not be paid in cash; if agent refuses to accept certified expense bill telegraph the facts to division engineer.

Rates will be checked in accounting department.

INVENTORIES. (FORM 7.)

At the end of each year, on Dec. 31, each assistant engineer, resident engineer, or other official having property of the railway company in his charge, will make out a full inventory of it, and forward same to the chief engineer through the division engineer.

The value of this inventory depends upon its being made promptly, and showing, in detail, what property the railway company owns, where it is located, and what it is worth. Division engineers will see that the above instructions are followed, and that the inventories are complete in every particular.

INSURANCE.

All buildings, important bridges, trestles and other structures liable to damage from fire will be reported to the chief engineer for insurance immediately on completion. Make these reports in tabulated form, as follows:

Description of buildings for insurance on the

.....

Place.	Use.	Station Opposite Center.	Distance and Direction from Main Track.	Dimensions of Ground Plan.	No. of Stories.	Kind of Structure.	Kind of Roof.	Value and Other Remarks.

Make special mention of engines, tools and machinery in shops, and of pumps, boilers and water supply pipes in pump houses.

Description of bridges for insurance on the

.....

No. of Bridge.	Station at ..... end.	Miles from	Character.	Length.	Value and other remarks.

Give piers and abutments as separate items. Include cost of rails in the value column. Bridges costing less than $400 need not be reported.

WORK TRAIN SERVICE.

Work trains will be controlled by assistant engineers or such other official as they may designate. They will be handled so

as to give the utmost possible service to contractors, and all reasonable requests made by the latter will be complied with.

Trainmen will be furnished by the operating department on request of the division engineer.

The transportation rules of the N. P. Ry. Co. will govern on all lines under construction.

Locomotives and enginemen will be furnished by the mechanical department on requisition made through the chief engineer's office.

Requisitions for engine and train supplies, including fuel, will be made direct on the division storekeeper or the division superintendent.

Time slips of enginemen and trainmen must be certified by assistant engineer, who will also note distribution on same, and take such record as will enable him to check bills rendered by the operating department at the close of the month.

All enginemen and trainmen will be borne upon the rolls of the division master mechanic and division superintendent.

RENTAL AND EQUIPMENT.

All necessary engines and cars required for construction of new lines will be furnished by the operating department at the following rates of rental per day:

Engines	$6.00
Coaches	4.00
Baggage cars	2.00
Regular cabooses	2.00
Box car cabooses	1.00
Boarding cars	1.00
Box boarding cars	.50
Box cars	.50
Flat cars	.33

Requisitions for engines and cars will be made through chief engineer's office, specifying the purpose for which required.

All conductors will make daily report on form 105 of all cars handled by them.

At the close of each month assistant engineers will forward all reports, form 105, to division engineer with a statement covering the same.

At end of every month each assistant engineer will make a report to his divison engineer of all cabooses, boarding cars, water tank cars, tool cars, etc., used on his work during the

month, giving car numbers, dates between which used, purpose for which used, and whether used by company or contractors.

From this report and the statement mentioned in paragraph 83, the bills of rental against construction department and contractors will be made up, in the division engineer's office.

Construction material must be promptly unloaded and cars returned at once to operating department.

Under no circumstances can foreign cars be used in work-train service, nor can any cars be used as cabooses or boarding cars, except those furnished for that purpose.

COMMERCIAL TRAFFIC DURING CONSTRUCTION.

The province of this department is to construct new roads, not to operate them, and they are to be turned over to the operating department as soon as practicable.

The object of these instructions is to relieve this department from handling money, and place the responsibility of properly collecting and accounting for revenue arising from transactions of commercial business in the hands of the officials of the railway company to whom such work belongs.

The accounting department will see that such earnings are duly credited to construction account.

Time cards will be arranged by assistant engineer with as much reference to convenient transaction of commercial business as is consistent with the economical handling of construction work.

Officers and employees are to handle no money collected for transportation of freight and passengers except as herein provided.

As soon as commercial business is likely to be offered, the assistant engineer shall notify the division engineer, who shall request the division superintendent under whose jurisdiction the branch will pass when completed to nominate agents and operators, subject to approval by the chief engineer and the proper officials.

The chief engineer will request the general traffic manager to publish freight and passenger rates.

A traveling auditor will be sent to install, instruct and bond station agents.

The division engineer will ask the division superintendent to furnish train crews.

The men so nominated and installed will be in the employ of and paid by construction department.

They will be directly under orders of the assistant engineer in everything, except collecting and remitting money, making waybills and reports, and keeping accounts. In these matters they will be under orders of and comply with instructions given by the accounting department and by the treasurer.

Conductors shall furnish the assistant engineer with duplicate reports of all collections to permit a check on same.

Neglect to comply promptly and fully with rules of these officials will be cause for dismissal.

Standard printed rules and regulations in force under operating department defining their duties will be furnished, and must be strictly complied with.

If Express, United States mail, or Western Union telegraph services are extended over the branch, agents, operators and conductors will transact the business in conformity with current practice on the adjacent main line.

When assistant engineers deem change of agents, operators, dispatchers, or conductors necessary, due and sufficient notice must be given to the division superintendent.

Agents must not be transferred from station to station or given leave of absence until checked out by traveling auditor and substitute duly installed.

The accounting department will provide outfit of stationery and blanks necessary to open new stations.

When no regular trains are run, conductors of work trains will collect, report and remit cash collections as provided in instructions to conductors of regular trains, and all work train conductors will follow same rules.

No person will be allowed to ride on regular trains without paying fare, unless provided with a pass.

Assistant engineers will make themselves familiar with rules and regulations in force on operating divisions, and see that their agents and conductors act in accordance therewith.

Assistant engineers stand in same relation to these employees as a division superintendent to his men.

NORTHERN PACIFIC BENEFICIAL ASSOCIATION.

Every resident and assistant engineer should know the name and address of the N. P. B. A. surgeon nearest to his work; this information can be obtained from division engineer.

Each engineer in charge of work will be furnished on requisition with a supply of N. P. B. A. printed forms, also book of instructions issued by the association.

In case of sickness or accident the employee should be given an order for treatment (form B. A. 100) by his immediate superior on the nearest N. P. B. A. surgeon.

In case of accident or serious illness where there is no N. P. B. A. surgeon available, call the nearest surgeon and immediately wire the facts to chief surgeon at Brainerd or Missoula (as the case may be), who will direct as to subsequent treatment. Send bills for treatment to division engineer, who will forward them to chief engineer. Bills should be itemized, and should be certified and have full explanation of the emergency indorsed by the official who called the surgeon.

Parties in the field distant from cities or towns will, upon application to the chief surgeon at Brainerd or Missoula, be provided with "a first aid package" and a supply of medicine, with instructions for use in case of emergency.

PASSES.

Books of passes will be furnished from the chief engineer's office to assistant engineers for issue to employees traveling on company business, or for discharged employees to the point on N. P. Ry. at which they were hired.

Passes will not be honored unless bearing written countersignature of the person authorized to do so, and conductors will decline to honor any pass signed or countersigned "by" or "per" any person.

Passes for families of employees, contractors or employees not traveling on company business, will be issued only on approval of chief engineer.

Whenever a book of passes is used, the stubs should be returned at once to chief engineer.

ACCIDENT REPORTS.

In case of accident on the railway or on the property of the company, resulting in death or personal injury, either to employees or others, employees must telegraph the facts immediately to the general claim agent at St. Paul and to the division engineer. This telegram must be confirmed by written report on the blank provided for the purpose and forwarded by first mail to the division engineer, who will transmit the same through the office of the chief engineer to the general claim agent.

If the injured employee is allowed compensation for time lost on account of injuries or other payment therefor, release of damages should be taken on form 256. Such allowance or payment should be made only on authority first obtained from the chief engineer.

Copy of special instructions issued by the general claim agent relative to use of release blanks will be furnished to engineers on application to the division engineer.

TELEGRAMS.

Messages should be sent by wire only when the mail service will not answer the purpose. There is a tendency to use the telegraph for communicating matters of small importance, simply because there is less care and time involved to the sender in one form than the other.

VII.

Supplies and Equipment for Field Parties.

SUPPLIES FOR 14 MEN, 30 DAYS.

400 lbs. Flour.
50 lbs. Buckwheat flour.
40 lbs. Oatmeal.
30 lbs. Cornmeal.
150 lbs. Sugar.
20 lbs. Salt.
10 lbs. Tapioca.
10 lbs. Sago.
10 lbs. Baking powder.
2 lbs. Mustard.
1 lb. Pepper, ground.
½ lb. Ginger, ground.
½ lb. Cinnamon, ground.
¼ lb. Allspice, ground.
100 lbs. Ham.
100 lbs. Bacon.
25 lbs. Dried beef.
25 lbs. Codfish.
400 lbs. Potatoes.
1 case Pears.
1 case Cherries.
2 cases Tomatoes.
2 cases Peaches.
2 cases Corn.
1 case Peas.
1 case Condensed milk.
50 lbs Coffee.
10 lbs. Tea.
40 lbs. Lard.
12 packages Yeast cakes.
25 lbs. Cheese.
50 lbs. Beans.
25 lbs. Rice.
10 lbs. Corn starch.
1 box Macaroni.
10 lbs. Barley.
1 box Soap.
1 bottle Lemon extract.
1 bottle Vanilla extract.
10 lbs. Currants.
1 box Raisins.
5 gallons Syrup.
6 bottles Pickles.
20 lbs. Onions.
1 gallon Vinegar.
6 bottles Tomato catsup.
1 case Corned beef.
3 lbs. Baking soda.
50 lbs. Evaporated apples.
50 lbs. Dried peaches.
50 lbs. Dried prunes or plums.
¼ lb. Nutmegs.
1 box Soda crackers.
12 boxes Matches.
1 box Candles.
2 lbs. Lye.
10 lbs. Sal soda.
60 lbs. Butter.
8 bottles Worcestershire sauce.
1 case Coal oil.

Eggs, fresh meat and vegetables as required, if they can be obtained from the farming community.

ENGINEER EQUIPMENT AND STATIONERY (FOR ONE FIELD PARTY.)

1 Transit.
1 Level.
1 Chain, 10 extra links, 1 extra handle.
4 Flag poles.
2 Level rods.
1 Hand level.
1 Barometer.
1 Clinometer.
1 Pocket compass.
1 Protractor, paper.
48 Thumb tacks.
6 Camel hair brushes.
1 Scale, triangular, decimal.
1 Straight edge, 36", steel, nickel-plated.
1 Drafting board and trestles.
1 Stationery chest, tray & board.
2 Hand axes and extra handles.
3 to 6 axes and extra handles.
1 Hatchet.
1 Water keg (2 galls.).
2 Brush hooks.
2 50-ft. Tapes in cases, 2 without cases.
1 bottle Mucilage.
2 bottles India ink.
1 Stick India ink.
1 pint Combined writing fluid, in stone bottle.
1 small bottle Red ink.
2 dozen Shipping tags, N. P. Ry.
2 dozen Shipping tags, N. P. Ex.
5 Transit books (form 60).
10 Level books (form 60).
10 Topography books (C. D. 61).

6 Scratch blocks.
12 Blotters.
1 Time check book.
1 doz. Property reports (form 11).
1 block Vouchers.
12 papers Tacks, 8-oz. tinned.
3 quires Wrapping paper.
2 balls Twine.
2 yds. Red flannel.
2 yds. White flannel.
1 Sounding rod, 3 joints, 8' each.
6 6-H Pencils.
12 4-H Pencils.
12 No. 2 Pencils.
12 Timber leads.
100 Manila envelopes, large.
100 Manila envelopes, small.
6 Colored pencils, red and blue.
12 Penholders.
1 box Assorted pens.
12 Crow quill pens.
1 Slab for India ink.
2 Inkstands.
1 Pocket inkstand.
2 Pads letter paper.
2 Pads note paper.
2 Pyramids pins.
6 Rubber erasers.
1 Steel eraser.
3 quires Foolscap.
3 quires Journal paper.
1 box McGill's paper fasteners.
50 sheets Cross-section paper, 10ths.
4 Triangles, 10, 8, 7 and 5 ins., 30° and 60°.
30 yds. Drawing paper, 24" wide.
1 roll Plate A profile paper, divided.
1 roll Tracing cloth, 30 ins.
1 Stylus book, with carbons.
24 Time returns (form 102).
1 Book of receipts (form 104).
1 Pad form B. A. 100.
1 Book N. P. B. A. rules and regulations.
1 Book transportation rules.
1 box Rubber bands, assorted.
2 Tin map cases, 6 × 36 ins.
2 lbs. Keil.
2 quires Legal cap.

In the case of extended explorations beyond civilization, apply to Chief Surgeon of the N. P. Beneficial Association for small supply of medicines and "first aid package" and instructions how to use them.

CAMP EQUIPMENT (FOR ONE FIELD PARTY).

4 Tents and flies, 14×14 or 14×16.
1 Grindstone.
1 Monkey wrench.
1 Spade.
1 Hand saw.
1 Cross-cut saw.
1 Alarm clock.
1 2-gall. Keg.
1 Washtub, board and boiler.
1 bundle Sail twine and needles.
1 Sail palm.
10 yds. Canvas.
2 Three-cornered files.
1 Flat file.
10 yds. Toweling.
1 Scrub Brush.
1 Broom.
3 Candlesticks.
3 Stand lamps and 6 chimneys.
2 Stewpans.
1 Water pail.
2 Griddles.
1 Coffee mill.
4 Drip pans, 12 × 17.
1 5-gall. Dishpan.
1 5-gall. Breadpan.
4 large iron Spoons, 12 ins.
1 Soup ladle.
1 Cake turner.
1 Steel.
3 Butcher knives.
1 Chopping bowl.
1 Chopping knife.
3 Pepper boxes.
1 Sieve.
1 Steamer.
1 Collander.
2 Can openers.
1 Meat saw.
1 Potato masher.
1 Rolling pin.
1 Nutmeg grater.
1 Bread board.
10 yds. Oil cloth.
1 Flesh Fork.
1 Biscuit cutter.
36 Teaspoons.
36 Tablespoons.
36 Knives.
36 Forks.
1 Carving knife.
1 Carving fork.
1 Tea kettle.
1 Tea strainer.
24 Coffee cups.
2 Candle lanterns.
3 Washbasins.
2 Dippers.
1 Lunch basket.
1 Dinner table.
2 Trestles for tables.
1 Cook table.

2 Sibley stoves, sheet iron.
1 Cook stove.
3 pieces Pipe, with dampers.
12 pieces Pipe without dampers.
2 Iron pots.
1 3-gall. Coffee pot.
1 2-gall. Tea pot.
1 large Frying pan.
1 small Frying pan.
2 No. 28 Stew kettles, galvanized iron.
24 pint Cups.
30 Plates.
12 Pie plates.
1 No. 24 Stew kettle, galvanized iron.
4 3-qrt. Pans.
4 4-qrt. Pans.
4 6-qrt. Pans.
18 pint Pans.
3 Tin pot covers.
2 3-gall. galvanized Water Pails.
1 2-gall. Tin water pail.
1 Pick and handle.
2 Mess chests.
5 lbs. 10d. Nails.
100 ft. ¾-in. Manila rope.

STATIONERY LIST.

CONSTRUCTION AND ENGINEERING DEPARTMENT

Form No.
7 Annual inventory.
11 Monthly inventory.
19 Daily record of track laying.
23 Report of rails and fastenings received.
59 Tie inspector's book.
60 Transit and level book.
61 Topography book.
62 Cross-section book.
94 Estimate sheet.
99 Force report.
102 Time returns.
104 Receipt book for cash ex-
105 Daily report of construction material moved by train.
106 Monthly statement of expenditures, branch lines.
107 Estimate sheet, buildings.
108 Estimate sheet, grading and bridging.
*109 Construction contract.
*109A General contract (First par-
*109B General contract (First party, singular).
110 Conductor's time and labor
111 Record of estimates, con-
112 Monthly approximate estimate of expenditures.
*114 Preliminary estimate of cost of new road.
*117 General specifications.
*118 Book of instructions to engineers.
119 Daily report of piles driven.
120 Weekly report bridge work.
121 Bridge inspection report.
123 Monthly report of bridges repaired.
124 Monthly report of bridges reconstructed.
126 Bridge record book.
131 Daily report of cars received and unloaded.
132 Improvement sketch.
*133 Specifications for erection iron and steel superstructure.
*133A Specifications for erection iron and steel superstructure.
135 Specifications for Howe truss
138 Force report blank.
*140 Track and ballast (book).
*168 Form of proposal, for use on branch lines.
*169 Form of proposal, for use on small pieces of work.
*170 Material book.
*171 Distribution record.

*Stock kept in office of Chief Engineer.

Estimating Overhaul in Earthwork.

By H. P. Gillette, Associate Editor Engineering News.

In railroad excavation it has been the custom to specify a limit of haul within which the contractor received a given price per cubic yard, as 20 cts. per cu. yd., but beyond which limit he received an additional price, as 1 ct. per cu. yd. for each 100 ft. of overhaul. This limit is termed the "free haul" limit and was usually fixed at 500 ft., or in some cases at 1,000 ft.

Due to the work involved in figuring this overhaul, and due to trouble arising from disputes over interpretation of specifications relating thereto, the overhaul clause has been very generally dropped from specifications. This we believe to be a mistaken policy in most cases. Where cuts are so heavy that steam shovels are used for practically all the work, then the element of haul is practically negligible, for, with contractors' locomotives and cars used with steam shovels, the cost of hauling varies little with the distance hauled. In such cases the overhaul clause can well be omitted.

In railroad work, where the cuts are generally made to balance the fills, earth is often moved with drag or wheel-scrapers, one-horse carts, two-horse wagons, or with small dump cars on rails. Wheel-scrapers are ordinarily considered cheaper than carts up to hauls of 500 ft.; hence contractors accustomed to bidding with the purpose of using wheelers largely, felt the necessity of having some clause in specifications that would enable them to tell to what extent wagons or carts would be used on any given job. Engineers very justly met this desire by the insertion of an overhaul clause. Had they not inserted some such clause protecting the contractor, the result would have been either a refusal to bid at all on the part of reputable contractors, or an unduly high price if they did bid. It may sound strange in these days of fierce competition and often of "cut-throat prices," to speak as if contractors ever had a voice in the matter of specifications, yet exactly such a state of affairs has at times existed. For example, in one locality the contractors held a meeting at which they voted not to bid upon any work where the specifications did not give a double

price for all earth carried past any opening in the road—that is, any place where a culvert or bridge was to be built. The specifications had to be drawn to meet this requirement.

With a view to guide the contractor so that he could make a comparatively close estimate of the cost of earthwork, engineers inserted the overhaul clause in early specifications. It was a wise and a fair thing to do, and the overhaul specification furthermore possessed the element of flexibility. Thus, supposing that after bids have been received for grading a piece of work according to profiles shown, a further study of the problem makes it apparent that radical changes in the location should be made. Then, if such changes are made, the average haul of the earth must necessarily be either greater or less than the average haul would have been under the old profile. If the haul is greater the contractor will present a claim for "extras"; if less, he will say nothing and the company is the loser. Whereas if an overhaul clause exists the payment is sure to be equitable, and no claims can arise for "extras" provided the wording of the clause is clear as to what constitutes "overhaul." This is a matter that merits attention, for there are several points over which controversy may arise unless the wording is clear.

Thus in Fig. 1 at Sta. 504, the fill passes into cut. Shall the contractor be allowed to move the cut between Stas. 503 and 504 to the fill between 504 and 505; or shall he be made to haul it the full 500 ft. of "free haul"? There are engineers unfair enough and unwise enough to take the latter stand, acting under some such general clause in the specification as this: "The engineer shall have full power to direct the method and manner of doing all work, not inconsistent with limitations prescribed in these specifications." As a matter of fact were a law suit to follow any such unjust ruling, there can be no doubt that the court would hold that the contractor should be permitted to move the earth as is customary in such work. This being so, it could easily be shown that, ordinarily, drag scrapers are used to move earth for the first one or two hundred feet, the ordinary method of attacking the toe of such a cut being with "drags," later using wheelers as the haul increases, finally using carts, or cars.

We see, therefore, that the contractor ordinarily hauls the earth just as short a distance as he possibly can before dumping it in the fill, and it is but just and right that he be permitted to do so.

There is a method of figuring overhaul that is sometimes advocated (see letter to Editor Engineering News, Mar. 14. 1891, signed "W. R. H.") wherein the center of mass of the whole cut and the center of mass of the corresponding fill are ascertained; then having found the distance apart of these centers of mass the free haul of say 500 ft. is subtracted. This difference is called the overhaul. Obviously this method gives a greater average overhaul than where the common method about to be described is used, and unless clearly specified in the overhaul clause this method should not be used. In Engineering News, of issue just referred to, there is described and illustrated a method of estimating overhaul which is simple, legal, and as exact as can be desired in practice.

The method is described in a letter to the Editor of Engineering News as follows in full:

Sir: In your issue of Jan. 31, a method of estimating overhaul by a profile of quantities, by S. B. Fisher, is published. I have used a method somewhat similar to that, which is illustrated in the accompanying diagram (Fig. 1). This method consists in plotting the quantities in the cuts and fills on ordinary profile paper, and preferably on the same paper on which the ordinary profile is plotted, using the same horizontal scale, and placing the stations for the quantity profile directly above or below those on the ordinary profile, as in Fig. 1. These quantities are final quantities calculated from the construction cross-section notes. Each cut and fill is plotted separately, cuttings in red (= heavy solid lines in Fig. 1), and fills in blue (= heavy dotted lines in Fig. 1): the origins or zero points being at the stations or plusses where the cut changes from cut to fill occur (= grade points).

The total quantity of cut or fill from a grade point up to a given station is plotted opposite that given station, so that in the curve of quantities thus made, an ordinate at any station represents the total quantity in the cut or fill the grade point (= 0.0 cut) up to that station.

By plotting backward (from the last grade point toward the first grade point of a cut) in the same manner we obtain two curves symmetrical about a horizontal line through their point of intersection, and which intersect in the center of gravity (strictly speaking, center of mass) of each cut and fill.

The method of using this profile of quantities can be best understood by referring to Fig. 1. The cut from Sta. 499 + 30 to Sta. 504 will be hauled into the fill from Sta. 504 to the bridge opening at Sta. 510 + 75.

A, B, C′ and A′, B, C are the quantity curves for this cutting plotted from the grade points in opposite directions. They intersect at B, at Sta. 500, which is therefore the center of gravity of the cutting. A, E, G, F is the quantity curve for the fill. It is plotted one way only, because this fill can be made by hauling one way only, on account of the bridge opening. Supposing that earth is paid for at 16 cts. per cu. yd. up to 500 ft. of haul with an addition of 1 ct. per cu. yd. for each additional 100 ft.

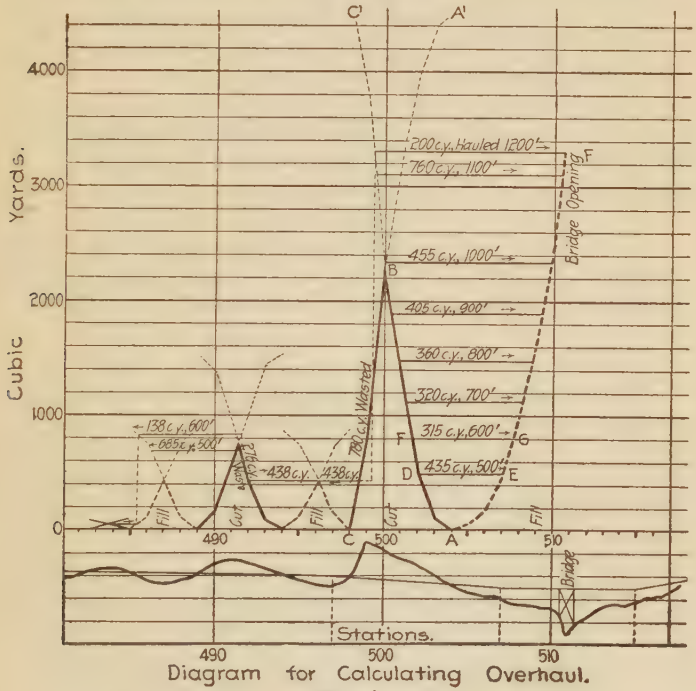


Diagram for Calculating Overhaul.

FIG. 1.

of haul: First find, with a scale or pair of compasses, the two points; one on the curve A B C′, and the other on A E G F, which are exactly 500 ft. apart on a horizontal line, and draw a line between them, the line D E. The points D and E represent the stations between which the extreme haul reaches 500 ft., and the ordinate at D (or at E which is the same in length) represents the number of cubic yards cut between the grade point A and the point D, all of which

is within the 500 ft. limit. Now find two points on these curves which are 600 ft. apart on a horizontal line, the points F and G. These mark the limits of the 500-ft. haul, and the vertical distance between D and F gives the quantity of earth hauled 600 ft. In the same way the quantity hauled 700, 800, 900 ft., etc., can be determined, and the stations which mark the limits of these different lengths of haul are found.

Having thus disposed of that part of the cutting from Sta. 499 + 30 to Sta. 504, we turn to the curve plotted backward from the grade point at Sta. 498, and find that by hauling backward from 498 + 50 to 496 + 20 (the center of gravity) we can make just half the fill at Sta. 496; the total quantity hauled being 438 cu yds., and the maximum distance 230 ft. The balance of the cut from 498 + 50 to 499 + 30, amounting to 780 cu. yds., must be wasted.

It will be readily seen from a study of this method that an engineer can tell in advance where to direct the contractors to borrow and where to waste, and can determine the most advantageous method of hauling out his cuts as soon as he gets his work cross-sectioned and his quantities calculated.

Of course, if rock is struck in unexpected places, and the quantities are thereby changed, it will be necessary to change the curves, and for this reason it is better not to ink in the quantity profile until the work is finished.

I am indebted to R. P. Bruer, C.E., of the C. P. R. R., for this method of calculating overhaul. T. S. RUSSELL.

Grant, Va.

It should be observed that earth ordinarily shrinks on being packed into a fill under the blows of horses' hoofs, etc., so that each 100 cu. yds. of cut make about 90 cu. yds. of fill. This factor is not mentioned by Mr. Russell, but should be considered by the engineer, if it is desired to get a very close estimate of overhaul.

The next method of estimating overhaul is essentially like the preceding one, although not as easily understood at first reading. It appeared in Engineering News, Jan. 31, 1891, as an article entitled "Estimating Overhaul in Earthwork by Means of the Profile of Quantities" by S. B. Fisher, chief engineer of the Minneapolis, St. Paul & Sault Ste. Marie Ry.

The article follows in full:

No facile, practical and accurate method of calculating the overhaul of earthwork is as yet in common use. The problem itself, consisting of finding the relations between the centers of gravity of known volumes in known positions may be, from the mathematician's point of view, a comparatively simple

one; but such a lack of readiness to solve it has the engineer shown that many a contract has been executed with the privilege of wasting and borrowing at the end of the haul. This practice results at times in waste of energy by the contractor, and still oftener in the waste of money to the other party to the contract. By the system of wasting and borrowing, material is paid for at the full price of excavation beyond the haul, but with the judicious use of overhaul, in many cases the material may be hauled half a mile before its price is doubled. When, from the increase of the traffic of a railroad, for example, it becomes necessary to grade for a second track, and in so doing to remove material wasted on the margin of a cut into an adjoining borrow pit along the neighboring fill, where it ought to have been deposited in the first place, it neither increases the respect of the later engineers for their predecessors, nor is it a credit to the profession.

Overhaul as commonly worked out is done in an approximate manner with the ordinary profile and the volumes in excavation and embankment. It takes longer to work it out

	Increments.		Ordinates.			Increments.		Ordinates.	
Station.	+.	—.	+.	—.	Station.	+.	—.	+.	—.
213 + 34...	...	...	...		240.....	224	...	...	6,155
214.....	...	370	...	370	241.....	200	...	...	5,955
215.....	...	843	...	1,213	242.....	180	...	...	5,770
216.....	...	779	...	1,991	243.....	185	...	...	5,585
217.....	...	724	...	2,715	244.....	156	...	...	5,429
218.....	...	902	...	3,617	245.....	102	...	...	5,327
219.....	...	570	...	4,187	246.....	59	...	...	5,258
220.....	...	391	...	4,578	247.....	...	14	...	5,272
221.....	...	457	...	5,035	248.....	...	70	...	5,342
222.....	...	535	...	5,570	249.....	...	83	...	5,425
223.....	...	678	...	6,248	250.....	...	78	...	5,503
224.....	...	723	...	6,973	251.....	...	65	...	5,568
225.....	...	344	...	7,317	252.....	...	70	...	5,638
226.....	...	193	...	7,510	253.....	...	124	...	5,762
227.....	...	156	...	7,666	254.....	...	181	...	5,943
228.....	...	244	...	7,910	255.....	...	189	...	6,132
229.....	...	221	...	8,131	256.....	...	85	...	6,217
230.....	...	356	...	8,487	257.....	55	...	...	6,052
231.....	...	317	...	8,804	258.....	156	...	...	5,896
232.....	...	83	...	8,887	259.....	102	...	...	5,794
233.....	161	...	...	8,726	260.....	146	...	...	5,658
234.....	328	...	...	8,398	261.....	206	...	...	5,452
235.....	464	...	...	7,934	262.....	237	...	...	5,215
236.....	493	...	...	7,441	263.....	250	...	...	4,965
237.....	411	...	...	7,030	264.....	274	...	...	4,691
238.....	367	...	...	6,663	265.....	47	...	...	4,644
239.....	284	...	...	6,379	266.....	...	6	...	4,650

with the "Profile of Quantities," of which a short example is engraved, but it is done completely and accurately.

The method of the profile of quantities was originated by Bruckner, a Bavarian engineer. It was presented by Cuhlman in his "Graphical Statistics" in 1868, and translated from that by F. Reineker, then (1871-3) Principal Assistant Engineer of the Pennsylvania Co., at Pitsburg, Pa., for the use of his department. This translation was procured there by the writer, and the method adapted to American practice in a great variety of railway work, and is here given with an example of work as actually executed.

The subject is presented, for convenience and clearness, in three steps:

1st. The Compilation of the Data. 2d. The Plotting of the Profile. 3d. The Taking Off of the Results.

1. The Compilation of the Data.—The paper containing the data is ruled in five vertical columns, see page 83.

The first column contains the station numbers. In practice the elemental volume is the total excavation or embankment in a full station, whether the station distance is 100 ft., 66 ft., or a number of meters. Plusses are not used, excepting at an occasional beginning or end of a subsection, although the system is flexible enough to apply to any regular or irregular subdivision of these elemental volumes.

In columns 2 and 3 are now entered the total increments or volumes of earthwork in excavation or embankment in successive stations. When excavation and embankment both occur within the limit of the same station the net amount only need be entered. If there is a special price for casting within the station another column may be introduced for it. Excavation is considered plus and embankment minus. The latter may be entered in red ink.

Columns 4 and 5 are now filled up by algebraic addition of columns 2 and 3. The ordinate at any point of the "Profile of Quantities" is equal to the algebraic sum of the volumes as far as to that point, and should be verified by use of this principle, at convenient points, as the summation proceeds.

2. The Plotting of the Profile.—The horizontal part of the plotting is the same as used in the ordinary profile, and it may

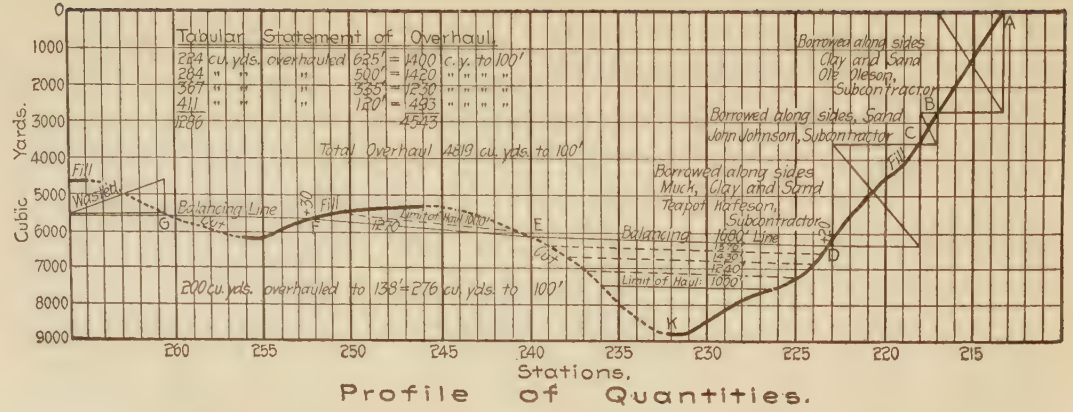

Tabular Statement of Overhaul.
284 cu. yds. overhauled 625' = 1400 c.y. to 100'
284 " " " 500' = 1420 " " " "
367 " " " 335' = 1230 " " " "
411 " " " 120' = 493 " " " "
1286 4543
Total Overhaul 4819 cu. yds. to 100'
200 cu. yds. overhauled to 138+276 cu. yds. to 100'
Borrowed along sides Clay and Sand Ole Oleson, Subcontractor
Borrowed along sides, Sand John Johnson, Subcontractor
Borrowed along sides Muck, Clay and Sand Teapot Hafeson, Subcontractor
Balancing Line
Limit of Haul: 1000'
Fill
Waste
Cut
Cubic Yards.
Stations.
Profile of Quantities.

FIG. 2.

be made on the same sheet of paper; but for the vertical part instead of elevations being referred to a datum plane, at or below the lower edge of the profile paper, we have an initial line or axis of abscissas, located somewhere on the profile, from which the ordinates are measured above for plus and below for minus. Connecting the ends of these ordinates, we have a broken line, which in mathematical language may be called a curve, resembling somewhat an ordinary profile, but wholly different therefrom, composed of the elements between the successive stations.

If the increment, by the use of which any ordinate is formed from the previous one, is positive, this element of the curve

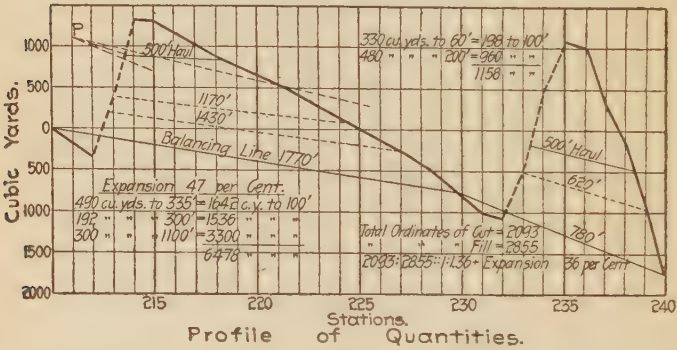


FIG. 3.

will incline upward, will indicate excavation and be shown by a dotted or blue line. If the increment is negative the element of the curve will incline downward, will indicate embankment and be shown in red or by a solid line. So that excavation on the profile of quantities is always shown by an ascending dotted or blue line, and embankment by a descending solid or red line.

We now consider the balancing line. Some points of this line are always fixed by the patent conditions of the work, and occasionally all points are so fixed, but very often some points on it are indeterminate at first, so that each section is very

likely to be a little problem by itself. The functions of the balancing line will most clearly be seen by referring to the engraved sample profile, Fig. 2. We have here the first point of it, A, the beginning of the section; B, the end of Ole Oleson's job; C, the end of John Johnson's job; D, the end of Teapot Kofeeson's job; E, at station 240, the dividing point between backward and forward hauls in the cut; F, station 252 + 30; J, junction point of forward and backward hauls in the fill; G, the point where waste commences in the second cut, and H, the end of the section.

The Taking Off of the Results.—From A to D there is no overhaul, but the nature of the material and any other items can be conveniently recorded there. The fill between D and K, is made from the cut between K and E. We first fix the position of the limit of haul (1,000 ft.) which here comes between stations 226 and 236, and then draw the intervening lines of overhaul to each point of flexure of blue and red lines. We now read the elements of the cut between these lines of haul, from the profile, or if we desire great accuracy, from the data prepared for plotting the profile and tabulate them. Each of these elements multiplied by its respective distance overhauled will give equivalent quantities overhauled to one station; as for example,

$$224 \text{ cu. yds.} \times \frac{1680 + 1570}{2} - 1000 = 224 \times 6.25 = 1390$$

The sum of these partial products will give the total overhaul for the cut. The tabulation should always be verified, by seeing that the sum of the elements of the blue or red curve, as the case is, is equal to the difference between the extreme ordinates.

If E to K is rock or D to K is a sink hole, the line E D will be inclined, and should be prolonged to an intersection with the horizontal through K. This intersection then becomes a pole, through which the lines of haul are drawn. The method is so flexible it can be applied to anything which can be executed in earthwork, and in addition gives a record of what has been done. It is also used to make the preliminary distribution of material before the work is begun. [The following is

from a letter by Mr. Fisher that was published in Engineering News, Feb. 7, 1901, further explaining the method.]

Referring to Fig. 3, prolong that portion of the balancing line which passes through Stas. 230 and 240 to the point P, its intersection with the horizontal line through Sta. 235; the lines of haul are drawn from this point to each point of flexure of the dotted and solid curves. The limit of haul is fixed by making the horizontal distance between the upper intersection 500 ft.

The swelling or shrinking of the material is shown by the relation between the extreme ordinates of the solid and dotted curves, as shown in Fig. 3. The balancing line is nearly always more or less inclined. It is horizontal only when the volumes of the adjacent cut and fill are equal to each other. The point P will not usually come within the limits of the drawing, and it is only in rare instances of great expansion or contraction of material that it is needed in practice. The inclination of the balancing line is generally so slight that the lines of haul can be drawn parallel to it or a trifle divergent.

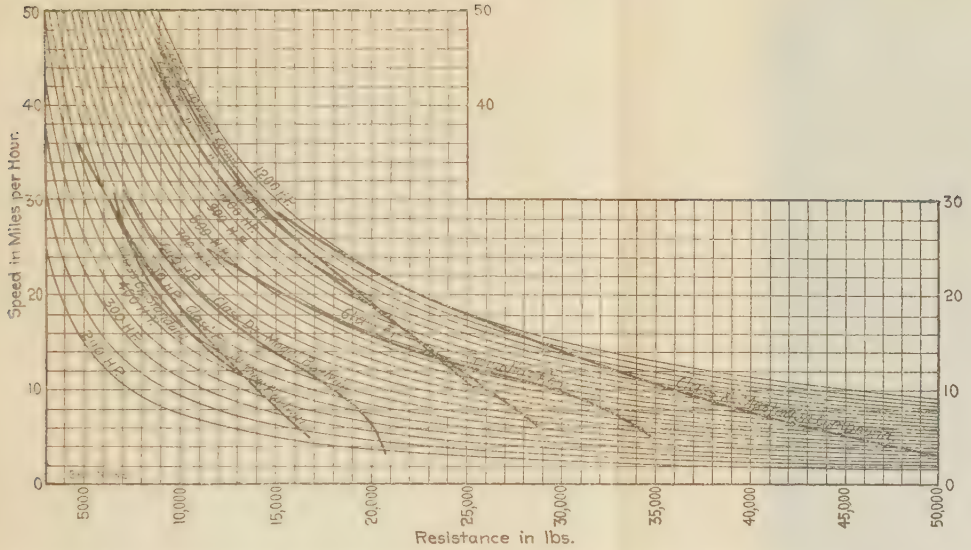
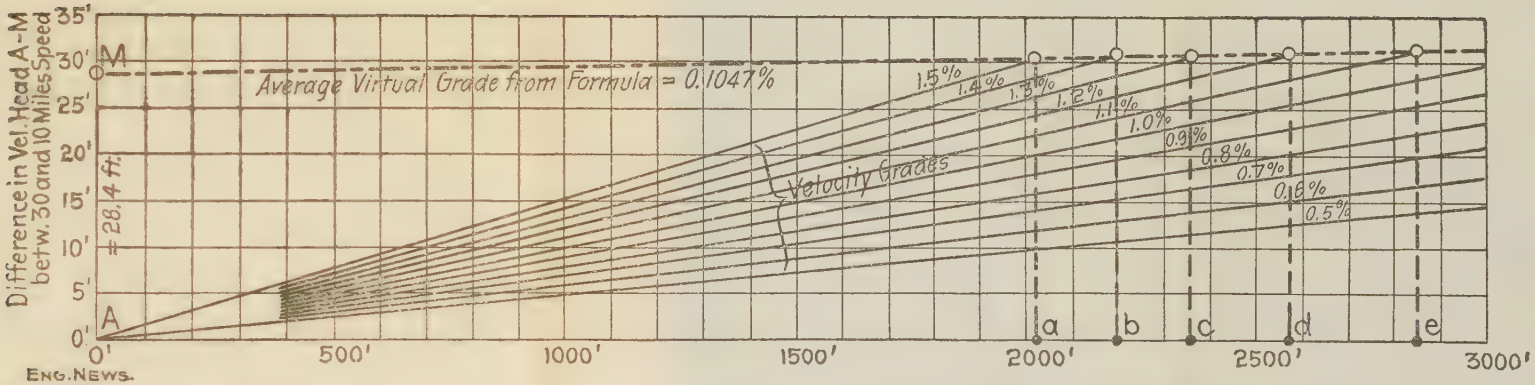


FIG. 1.—CURVES SHOWING HORSE-POWER OF STANDARD LOCOMOTIVES; NORTHERN PACIFIC RY.

Table of Mean Cylinder Tractive Power.

Speed in miles per hour.....		Initial speed.....	45	40	35	30	25	20	15	10
		Terminal speed.....	10	10	10	10	10	10	10	10
Class X.....	Mastodon compound. Weight on drivers, 150,000 lbs. " " eng. & tendr, 270,720 lbs.		.....	.....	.....	23,607	26,094	29,050	32,433	36,000
Class P.....	10-wheel compound. Weight on drivers, 112,000 lbs. " " eng. & tendr, 249,500 lbs.		16,057	17,071	18,219	19,521	20,947	22,432	23,917	25,400
Class R.....	10-wheel compound. Weight on drivers, 126,600 lbs. " " eng. & tendr, 264,530 lbs.		15,575	16,618	17,819	19,212	20,822	22,545	24,267	26,000
Class F 1....	Consolidation. Weight on drivers, 135,000 lbs. " " eng. & tendr, 227,600 lbs.		.....	.....	.....	.....	18,934	21,659	25,100	29,300
Class D 3....	Mogul, Baldwin. Weight on drivers, 85,900 lbs. " " eng. & tendr, 175,290 lbs.		.....	.....	....	11,743	12,921	14,355	16,058	17,850
Class E 2....	10-wheel Baldwin. Weight on drivers, 76,700 lbs. " " eng. & tendr, 117,700 lbs.		.....	.....	8,942	9,755	10,653	11,664	12,800	14,050
Class C 2....	Standard. Weight on drivers, 55,500 lbs. " " eng & tendr, 154,260 lbs.		.....	.....	.....	9,490	10,270	11,314	12,690	14,500



Formula for Determining the Average Virtual Grade.

$$S_v = \frac{1}{20}\left[\frac{T}{W} - R\right]. \qquad (1)$$

S_v = average virtual grade expressed in per cent.;
T = mean cylinder tractive power in lbs. for given initial and terminal speed;
W = weight of train in tons of 2,000 lbs., including engine and tender;
R = mean train resistance in lbs. per ton of train.

NOTE.—The maximum virtual grade for a given trainload (W) is found by inserting in above formula the train resistance (R) and the cylinder tractive power (T) for minimum speed (10 miles per hour).

Example: In above diagram is shown the length of velocity grades for engine Class D 3 Mogul, pulling a train weighing 1,250 tons (including engine and tender) for an initial speed of 30 miles and a terminal speed of 10 miles per hour.

Table of Mean Train Resistance in Pounds per Ton for Loaded Cars.

Speed—Initial.	Speed—Terminal.	R.
45	10	10.6
40	10	9.4
35	10	8.3
30	10	7.3
25	10	6.5
20	10	5.8
15	10	5.2
10	10	4.7

The difference in velocity heads (A M) taken from Table of Velocity Heads = 31.95 − 3.55 = 28.4 ft.

The average virtual grade (S_v) is calculated from formula:

$$S_v = \frac{1}{20}\left[\frac{T}{W} - R\right] = \frac{1}{20}\left[\frac{11{,}743}{1{,}250} - 7.3\right] = 0.1047\%.$$

T = 11,743, taken from table of mean cylinder tractive power;
R = 7.3, taken from table of mean train resistance.

The length of velocity grades from A to a, b, c, d, e, etc., is found by construction, as shown in the above diagram, or may be found by calculation from the formula

$$l = \frac{d}{S - S_v},$$

in which l = length in stations of 100 ft.; d = difference in velocity heads for the given initial and terminal speed; S = actual grade in per cent., and S_v = virtual grade, as found from formula (1). The maximum virtual grade of the above example is

$$= \frac{1}{20}\left[\frac{17{,}850}{1{,}250} - 4.7\right] = 0.479\%.$$

Table of Velocity Heads.
(Vel. head = $0.0355\,v^2$.)
v = speed in miles pr hr.

Speed in miles pr hr.	Velocity-head in ft.	Speed in miles pr hr.	Velocity-head in hr.
10	3.55	28	27.83
11	4.30	29	29.86
12	5.11	30	31.95
13	6.00	31	34.12
14	6.96	32	36.35
15	7.99	33	38.66
16	9.09	34	41.04
17	10.26	35	43.49
18	11.50	36	46.01
19	12.82	37	48.60
20	14.20	38	51.26
21	15.67	39	54.00
22	17.19	40	56.80
23	18.79	41	59.68
24	20.46	42	62.62
25	22.20	43	65.64
26	24.00	44	68.73
27	25.88	45	71.89